RECLAMATION

Managing Water in the West

Technical Memorandum

Water Budget Methodology

Westside Salt Assessment, California
Mid-Pacific Region

Draft

U.S. Department of the Interior
Bureau of Reclamation

March 2010

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Abbreviations and Acronyms

Basin Plan	Water Quality Control Plan for the Sacramento and San Joaquin River Basins
BMP	best management practice
C2VSim	California Central Valley Simulation (Model)
CDEC	California Data Exchange Center
cfs	cubic feet per second
CIMIS	California Irrigation management Information System
CVGSM	Central Valley Groundwater Surface Water Model
CVHM	Central Valley Hydrologic Model
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CV-SALTS	Central Valley Salinity Alternatives for Long-Term Sustainability
D-1641	SWRCB Water Right decision 1641
DAU	Detailed Analysis Unit
Delta	Sacramento-San Joaquin Delta
DPR	California Department of Pesticide Regulation
DWR	California Department of Water Resources
EIS/EIR	Environmental Impact Statement/Environmental Impact Report
EPA	U.S. Environmental Protection Agency
ESA	Federal Endangered Species Act
ET	evapotranspiration
ETo	reference crop evapotranspiration
GEA	Grasslands Ecological Area
GIS	geographic information system
gpcd	gallon per capital per day
IGSM	Integrated Groundwater Surface Water Model
IWFM	Integrated Water Flow Model
IWRP	Integrated Water Resources Plan
Jones Pumping Plant	C.W. “Bill Jones Pumping Plant
Kc	crop coefficient
M&I	municipal and industrial
MAA	Management Agency Agreement

MP	milepost
NAD	North American Datum
NLDC	National Land Cover Data
NCDC	National Climate Data Center
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
SJF	San Joaquin River
SJRIO	San Joaquin River Input Output (Model)
SLDMWA	San Luis and Delta-Mendota Water Authority
SOW	scope of work
State	State of California
SWP	State Water Project
SWRCB	State Water Resources Control Board
TM	Technical Memorandum
TMDL	total maximum daily load
UCD	University of California at Davis
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
Vernalis	Airport Way Bridge near Vernalis
WARMF	Watershed Analysis Risk Management Framework
WetManWim	Wetland Management Simulation Model
WestSim	Westside Simulation Model

Chapter 1
Introduction

The CALFED Bay-Delta Authorization Act of 2004 directed the U.S. Department of the Interior, Bureau of Reclamation (Reclamation), to develop and implement a Program to Meet Standards. The purpose of the program is to "provide greater flexibility in meeting existing water quality standards and objectives for which the Central Valley Project has responsibility in order to reduce reliance on releases from New Melones Reservoir for those purposes" (Reclamation, 2006).

Section 3406(g) of the Central Valley Project Improvement Act (CVPIA) of 1992 (Public Law 102-575) specifically authorizes the development of water quality data and models for the Sacramento, San Joaquin, and Trinity river watersheds. One of the purpose of these tasks and models is to improve the scientific understanding of the "water budget of surface and groundwater supplies, considering all sources of inflow and outflow available over extended periods" to better evaluate existing and alternative operations of private and public water facilities.

As part of a watershed assessment, Reclamation seeks to identify salt sources, transport, and fate within the Westside Salt Assessment Westside Region of the San Joaquin River Valley. This project is referred to as the Westside Salt Assessment. Through this work, Reclamation hopes to improve implementation of its Management Agency Agreement (MAA) with the Central Valley Regional Water Quality Control Board (CVRWQCB) and reevaluate its strategy under the Program to Meet Standards. This Technical Memorandum (TM) presents the proposed approach for completing Task 2 of the scope of work (SOW): Westside Region Water Budget.

Chapter 1 of this document briefly describes the study area for the Westside Salt Assessment, its general characteristics, and previous water budget studies conducted for the Westside Region.

Study Area Definition

The San Joaquin River basin covers 15,880 square miles and includes the entire area drained by the San Joaquin River. The basin includes all watersheds tributary to the San Joaquin River and the Sacramento-San Joaquin Delta (Delta) south of the Sacramento and American river watersheds (Central Valley RWQCB, 2004). The lower San Joaquin River watershed covers the portion of the watershed downstream from Friant Dam.

The Central Valley RWQCB has defined seven subareas within the lower San Joaquin River watershed. The subareas on the westside of the San Joaquin River are as follows (Central Valley RWQCB, 2009):

- The **Grasslands Subarea** drains approximately 1,370 square miles on the west side of the San Joaquin River in portions of Merced, Stanislaus, and Fresno counties. This subarea includes the Mud Slough, Salt Slough, and Los Banos Creek watersheds. The eastern boundary of this subarea is generally formed by the lower San Joaquin River between the Merced River confluence and Mendota Dam.

- The **Northwest Subarea** drains approximately 574 square miles and generally includes lands on the west side of the San Joaquin River between the Airport Way Bridge near Vernalis and the Newman Wasteway confluence. This subarea includes the entire drainage area of Orestimba, Del Puerto, and Hospital/Ingram creeks. The subarea is primarily located in western Stanislaus County except a small area that extends into Merced County near the town of Newman and the Central California Irrigation District Main Canal. The Northwest Subarea is composed of three minor subareas, as follows:

  – The **Greater Orestimba Minor Subarea** is a 285 square mile subset of the Northwest Side Subarea located in southwest Stanislaus County and a small portion of western Merced County. It contains the entire Orestimba Creek watershed and the remaining area that drains into the lower San Joaquin River from the west between the Crows Landing Road Bridge and the confluence of the Merced River, including Little Salad and Crow Creeks.

  – The **Westside Creeks Minor Subarea** is comprised of 277 square miles of the Northwest Side Subarea in western Stanislaus County. It consists of the areas that drain into the west side of the San Joaquin River between Maze Boulevard and Crows Landing Road, including the drainages of Del Puerto, Hospital, and Ingram Creeks.

  – The **Vernalis North Minor Subarea** is a 12 square mile subset of land within the most northern portion of the Northwest Side Subarea. It contains the land draining to the San Joaquin River from the west between the Maze Boulevard Bridge and the Airport Way Bridge near Vernalis.

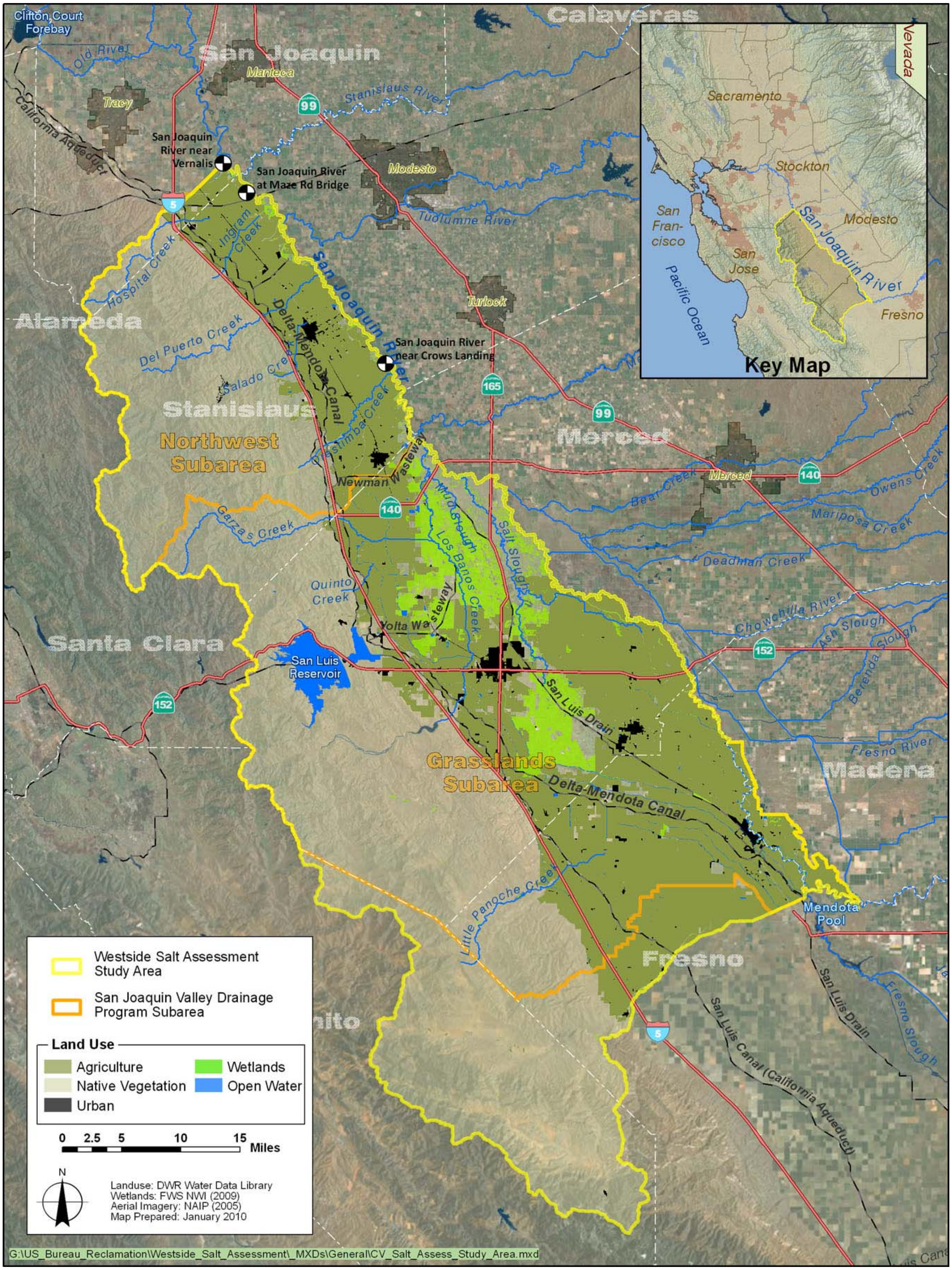

Figure 1-1. Westside Salt Assessment Study Area

The study area for the Westside Salt Assessment is shown in Figure 1-1. It encompasses areas that receive water from the CVP, and that potentially disposes all or a portion of that water to the lower San Joaquin River. The study area primarily comprises the Grasslands Subarea and Northwest Subarea, but also includes a small area to the west of the Grassland Subarea to cover the entire eastward-draining watersheds of the coastal hills, and the Panoche Creek watershed south of the Grassland Subarea that drains to the Mendota Pool/Fresno Slough. It is noted that the “westside” study area does include lands served by the Columbia Canal Company that lie “eastside” of the San Joaquin River.

Previous Studies

The following sections briefly describe previous studies of the water resources of the study area and relevant regions along westside of the San Joaquin Valley, and analytical tools that have been applied to this region to develop a water budget. No recent water resources studies have focused specifically on the Northwest Subarea. Rather, this subarea has been addressed in the context of water demands and water supplies of CVP contractors, and in the CVP contract renewal process. In contrast, numerous studies have addressed the Grasslands Subarea since the discovery of environmental problems related to selenium in agricultural drainage water in the 1980s. Studies conducted in this area include those of Burt and Katen (1988), Ayars and Schrale (1989), Gronberg and Belitz (1992), Belitz et al. (1993), Fio and Leighton (1994), Irrigation Training and Research Center (1994). More recent studies by the San Luis and Delta-Mendota Water Authority (SLDMWA) (2006), and the United States Geological Survey (USGS) in partnership with Reclamation (Brush et al., 2004) have investigated changes in water use within the Grasslands Subarea since the beginning of the Grasslands Bypass Project in 1996.

Groundwater Studies

Several studies have addressed groundwater conditions for the Westside of the San Joaquin Valley. These studies have applied local and regional groundwater models to assess subsurface impacts and the influence of subsurface drainage to surface water drainage along the Westside.

California Department of Water Resources Study of the Central Valley

The California Department of Water Resources (DWR) developed and maintains the Integrated Water Flow Model (IWFM), an integrated hydrologic model that couples a finite element groundwater model with a one-dimensional stream model, and includes a land surface root zone component to estimate stormwater runoff. The IWFM also includes agricultural irrigation and municipal water demands, groundwater pumping, and groundwater recharge (DWR, 2008). The current version of the model is Version 3.01, which was released in June 2008.

DWR has applied the IWFM code to create a water resources model of the Central Valley that simulates evolution of the groundwater system over the historical period of October 1921 to September 2003 using a monthly time-step. This application is known as the California Central Valley Simulation Model (C2VSim). C2VSim represents the groundwater system by three layers, each with 1,393 elements. Land surface processes are simulated using 21 subregions corresponding to DWR's water-supply planning areas (DWR, 2010). An initial calibration of the model has been completed.

U.S. Geological Survey Study of Central Valley Aquifer System

The Groundwater Resources Program of the U.S. Geological Survey (USGS) has assessed in detail the Central Valley aquifer system. The principal product of the assessment is the Central Valley Hydrologic Model (CVHM), which simulates surface water and groundwater flows across the floor of the Central Valley for water years 1962 to 2003 using a monthly time-step.

Groundwater is simulated using the USGS numerical modeling code MODFLOW-2000, a square-mile grid cell, and 10 vertical layers. The Farm Process for MODFLOW is used to simulate surface water deliveries, flow, and groundwater pumping for 21 "water balance regions" (these correspond to the C2VSim regions). The Farm Process module dynamically determines groundwater recharge and groundwater pumping based on crop water demands, surface water deliveries, and depth to the water table.

CVHM represents the Westside study area by a single water budget area, region 10 ("Delta-Mendota Basin," which is equivalent to DWR Depletion Study Area 49A). The coarse spatial resolution of CVHM for representing the surface water system limits use of the model for the Westside Salt Assessment.

Surface Water Studies

Numerous surface water studies have been completed to look at total salt and nitrate loading in the San Joaquin River watershed and the inter-relationships between water supply and drainage issues and their effect on river water quality. Many of these studies are related to CVP water contracting along the Delta-Mendota Canal and water diverted from the Mendota Pool.

San Joaquin River Input Output Model

In 1987, the State Water Resources Control Board (SWRCB) and University of California at Davis (UCD) jointly developed the San Joaquin River Input Output Model (SJRIO) to predict San Joaquin River water quality for regulatory purposes. SJRIO uses mass balance accounting to calculate monthly flow and salt loads of the San Joaquin River from Lander Avenue to Vernalis. SJRIO inputs and outputs include flow and salt loading for tile drainage, groundwater flow, accretions/depletions, Westside surface/subsurface agricultural discharges, riparian and pre-1914 and post-1914 appropriative diversions. The last update to the model (SJRIO Version 3) was made in 2003, and is capable of simulating the historical period of October 1977 to September 2000.

Grasslands Area

As part of a larger study, USGS, in cooperation with Reclamation, completed a study to estimate groundwater recharge and groundwater pumping in the "Grasslands Area," an area that comprises both the Grasslands Drainage Area and a portion of Westlands Water District, and is situated north of Cantua Creek (Brush et al., 2004). Crop water demands were estimated for each water year between 1972 and 2000 based on crop acreages, daily reference crop evapotranspiration (ETo), and daily crop coefficients (Kc values). Recharge and irrigation pumping were subsequently estimated for 11water budget areas (i.e., unique catchment areas within the Grasslands/Westlands study area) using root-zone soil moisture accounting. Groundwater pumping for irrigation was assumed to be the difference between crop water demand and effective precipitation and surface water deliveries. Irrigation and infiltrated precipitation that exceeded crop water demand was assumed to recharge the underlying aquifer.

Central Valley Project Contract Renewal

Following completion of the Programmatic Environmental Impact Statement (PEIS) for the CVPIA, Reclamation prepared environmental documents for the renewal of water service contracts with districts within the Delta-Mendota Canal Unit and San Luis Canal Unit of the CVP (Reclamation, 2005a, 2005b). Water needs assessments were completed for contractors who owned more than 2,000 acres of irrigable land, and whose contract total was greater than 2,000 acre-feet. Crop acreages, cropping patterns, crop water needs, effective precipitation, and conveyance loss information provided by each contractor were reviewed for agricultural water use. Residential, commercial, industrial, institutional, recreational, and environmental uses, along with landscape coefficients, system losses, and landscape acreage information provided by each contractor, were reviewed for municipal and industrial (M&I) water use.

Drainage Studies

Several studies have focused solely on drainage in the San Joaquin Valley in response to significant impacts in soil, groundwater, and surface water quality from naturally occurring selenium and small upstream watersheds and salinity from water diverted from the Delta-Mendota Canal and Mendota Pool.

San Joaquin Valley Drainage Program

The San Joaquin Valley Drainage Program was created by Reclamation and the State of California (State) in response to selenium-related issues at Kesterson Reservoir. The final report, published in 1990, recommended an in-valley drainage solution, which included source reduction, drainage reuse, land retirement, evaporation basins, groundwater management, and San Joaquin River discharge (SJVDP).

San Joaquin Valley Drainage Authority

The San Joaquin Valley Drainage Authority, including districts in the Grasslands Subarea, was formed to develop a long-term solution for drainage problems in the San Joaquin River basin, including out-of-valley disposal (e.g., piping water directly to the Pacific Ocean).

San Joaquin Drainage Monitoring Program

In partnership with other agencies and organizations, the San Joaquin District of DWR has monitored agricultural drainage water in the San Joaquin Valley since 1959. DWR currently collects samples and measures flows at 43 subsurface drainage sumps; 23 of these stations lie within the Westside Salt Assessment study area.

University of California at Davis Monitoring Program

In 2002, the Central Valley RWQCB executed an interagency agreement with UCD to conduct an evaluation of the water quality of agricultural drains throughout the Central Valley. Several sites are located within or adjacent to the study area.

Westside Integrated Water Resources Plan

The 2006 Westside Integrated Water Resources Plan (IWRP) was developed by SLDMWA in cooperation with Reclamation and local stakeholders. Its purpose is to guide future water management programs affecting the Westside Region.

The Westside IWRP contains a water supply (and water demand) gap analysis for CVP water service contractors within the Delta Division, San Luis Unit, and San Felipe Division of the CVP. San Joaquin River Exchange Contractors are not included in the analysis because water supplies to these contractors have not been adversely affected by requirements of the Endangered Species Act (ESA), CVPIA, or SWRCB Water Right Decision 1641 (D-1641). Similarly, the water supply gap analysis does not consider managed wetlands. The gap analysis identifies water supply, water use, and water shortages at 1999 and 2025 development levels and is based on the Year 2000 *Water Needs Analysis* conducted by Reclamation (unpublished).

The Westside IWRP identifies a series of water management strategies to address water supply and drainage issues. One of the major strategies is the elimination of subsurface agricultural drainage as part of the *Westside Regional Drainage Plan* (San Joaquin River Exchange Contractors Water Authority, et al., 2003). Key elements of the drainage plan include land retirement, groundwater management, source control, reuse, treatment, and salt disposal (SLDMWA, 2006).

Report Organization

This TM includes the following topics:

- Background, study area, and description of previous studies (Chapter 1).
- Summary of study area characteristics (Chapter 2).
- Approach to establishing a set of volumetric water budgets for the study area (Chapter 3).
- Summary of the modeling tools will be used to develop the water budgets (Chapter 4).
- Summary of data requirements and data sources that are needed for model update and refinement (Chapter 5).
- Overview of model workflow and data sharing for Westside Region water budget analyses (Chapter 6).
- A list of sources used in preparing this TM (Chapter 7).

Chapter 2
Study Area Characteristics

This chapter discusses study area characteristics relating to water supply and water use.

Physical Environment

The physical environment represents the land topography and soil conditions that affect the flow of water across the study area. Quantifying and tracking of both applied irrigation water and precipitation is an important element in the assessment of water sources and their fate through surface and hydrogeologic features in each catchment area within the study area.

Climate

The San Joaquin Valley has an arid to semiarid climate characterized by hot summers and mild winters. The study area lies in the rain shadow of the Coast Range and is relatively dry compared to the eastern side of the San Joaquin Valley. Precipitation decreases from north to south and from east to west. Average annual precipitation within cultivated lands of the study area varies from 8.5 to 12.0 inches per year.[1] Potential ETo increases from north to south; average annual ETo is approximately 55 inches per year.

Geology and Soils

Soils within the study area are derived from the erosion of the marine rocks that form the Coast Range. These soils contain salt and other trace elements such as arsenic, boron, selenium, and molybdenum. Salts within the root zone are leached into the shallow groundwater by precipitation and irrigation.

Water Supplies

The study area is a highly managed hydrologic system due to the diversion and storage of perennial flows from the basin at Friant Dam. Water supplies for agricultural purposes are imported into the basin from the Delta through the Delta-Mendota and San Luis canals, and are supplemented by San Joaquin River diversions downstream from Lander Avenue and by groundwater pumping.

[1] Based on an analysis of PRISM data for 1970 through 2000.

California Aqueduct

The California Aqueduct approximately runs along the western boundary of the valley floor, conveying water from the Clifton Court Forebay in the Delta to Central and Southern California. The section of the California Aqueduct between Check 13 (Milepost (MP) 70.85) and Check 21 (MP 172.40) is a joint facility, shared by Reclamation and DWR, and known as the San Luis Canal. CVP water from the "Joint Reach"[2] is delivered to CVP contractors located in the San Joaquin River and Tulare Lake hydrologic regions[3]. Other shared Federal-State facilities within the study area include the Gianelli Pumping-Generating Plant and San Luis Reservoir. Oak Flat Water District is the only State Water Project (SWP) contractor located within the study area. The district is located north of the O'Neill Forebay and receives deliveries directly from the California Aqueduct.

Delta-Mendota Canal

The Delta-Mendota Canal is located downslope from the California Aqueduct and is operated by Reclamation and SLDMWA. The canal stretches 117 miles from the C.W. "Bill" Jones Pumping Plant (Jones Pumping Plant) in the south Delta to the Mendota Pool on the San Joaquin River near the town of Mendota, 30 miles west of Fresno. The canal initially runs south along the western edge of the San Joaquin Valley, parallel to the California Aqueduct, but diverges from the aqueduct after passing San Luis Reservoir. Water may be pumped from the canal through the O'Neill Pumping-Generating Plant into the O'Neill Forebay, and then into San Luis Reservoir by the Gianelli Pumping-Generating Plant. Water from San Luis Reservoir may be released back into the canal, or diverted through the Pacheco Tunnel to the CVP San Felipe Division.

Stormwater runoff from upstream watersheds flows into both the California Aqueduct and Delta-Mendota Canal. There is seepage from these canals into the underlying groundwater and, during wet hydrologic periods, groundwater accretions to the lower reaches of the Delta-Mendota Canal. Seasonal groundwater extractions also occur by private well owners that are discharged directly into the Delta-Mendota Canal. Water from both the California Aqueduct and the Delta-Mendota Canal is temporarily stored in San Luis Reservoir during the fall and winter months and released in the spring and summer to supplement direct deliveries from the Delta. As a result, salinity can vary significantly along the length of both canal systems.

Lower San Joaquin River

The Vernalis gage on the San Joaquin River is regarded as the furthest downstream boundary that separates the San Joaquin Valley from the Delta; it is the most downstream flow measurement station on the river not subject to tidal influence. At the Vernalis gage, the San Joaquin River drains approximately

[2] In this document, the joint facility is referred to as the "Joint Reach" to avoid confusion with the San Luis Canal, which is owned and operated by the Exchange Contractors.

[3] State Department of Water Resources divides the state into 10 hydrologic regions for planning purposes. The Central Valley comprises the Sacramento River, San Joaquin River, and Tulare Lake hydrologic regions.

13,500 square miles of watershed area bounded by the Sierra Nevada Mountains to the east, the Coastal Range to the west, and the Tulare Lake Basin to the south.

Downstream from Friant Dam, the San Joaquin River can be subdivided into six reaches: Friant Dam to Gravelly Ford (Reach 1); Gravelly Ford to Mendota Pool (Reach 2); Mendota Pool to Sack Dam (Reach 3); Sack Dam to Bear Creek (Reach 4); Bear Creek to the Merced River (Reach 5); and the Merced River to the Vernalis gage (Reach 6). Reach 3 lies within the study area, while Reaches 4, 5 and 6 form the eastern boundary of the study area.

Reach 1: Friant Dam to Gravelly Ford

Friant Dam is located on the San Joaquin River, 25 miles northeast of Fresno. The dam controls San Joaquin River flows, provides downstream releases to meet requirements above the Mendota Pool, and provides flood control and conservation storage, and delivers water to a million acres of agricultural land in Fresno, Kern, Madera, and Tulare counties in the San Joaquin Valley. This reach of the river is not considered in the proposed water budget for the Westside Region.

Reach 2: Gravelly Ford to Mendota Pool

Reach 2 extends from the Gravelly Ford gage station to Mendota Dam. There are significant flow losses into the river bed downstream from Gravelly Ford caused by a combination of low groundwater levels and sandy soils. Prior to the San Joaquin River Restoration Program[4] Interim Flows, no flow occurred in Reach 2 except during periods of high flows and substantial releases from Friant Dam. For flood control purposes, flows greater than 2,500 cubic feet per second (cfs) are diverted from the San Joaquin River into the Chowchilla Bypass at the Chowchilla Bypass Bifurcation Structure[5]. Flow measurement at the San Joaquin River gage below the Chowchilla Bypass (DWR gage B07798) provides the upstream boundary condition for the proposed water budget along the San Joaquin River.

Under historical conditions, winter and spring flood flows from the Kings River entered Fresno Slough, which discharges into the San Joaquin River at the Mendota Pool. Since 1954, flood flows on the Kings River have been regulated by Pine Flat Dam, reducing the frequency and magnitude of flood spills to Fresno Slough. The Kings River is now operated to convey the first 4,750 cfs of flow to the San Joaquin River (the published capacity of the channel downstream from Mendota Dam is 4,500 cfs).

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[4] The San Joaquin River Restoration Program (SJRRP) is a comprehensive long-term effort to restore flows to the San Joaquin River from Friant Dam to the confluence of Merced River and restore a self-sustaining Chinook salmon fishery in the river while reducing or avoiding adverse water supply impacts from restoration flows.

[5] The Chowchilla Bypass Bifurcation Structure is a gated structure that is used to divert flood flows from the San Joaquin River into the Chowchilla Canal Bypass and limit flows past Mendota Dam to 4,500 cfs. Operation of the structure depends on both Kings River inflows from James Bypass and water elevations at the Mendota Pool. Mendota Dam can pass up to 1,500 cfs through sluice gates in the dam. The check boards in Mendota Dam must be removed to pass flows in excess of 1,500 cfs.

Reach 3: Mendota Pool to Sack Dam

Reach 3 extends from Mendota Dam to Sack Dam. Landowners adjacent to this river reach rely on water supplies diverted from the Mendota Pool, tailwater reuse, and groundwater; there are no riparian diversions between the Mendota Pool and Sack Dam.

The first dam at Mendota was constructed first by Miller & Lux holdings (a corporation formed to build the canal system) in 1871 to provide sufficient water depth to divert water into diversion canals upstream from the dam. As part of negotiations to allow the construction of Friant Dam, a group of water right holders (with Miller & Lux water rights dating back to the 1870s) exchanged San Joaquin River water for water considered surplus in the Sacramento River system. Their legal water right diversion points are located at Lone Willow Slough, Mendota Pool, and Sack Dam.[6] This exchange allowed water pumped from the Delta to be delivered to the Exchange Contractors at the Mendota Pool through the Delta-Mendota Canal to satisfy irrigation demands. The agreement includes an accord that the Exchange Contractors will receive water from Friant Dam if Reclamation is unable to provide adequate Delta water supplies through the Delta-Mendota Canal. In addition, the Exchange Contractors retain the right to divert San Joaquin River water when excess flows are released into the river from Friant Dam. Although construction of Friant Dam was completed in 1942, current operations did not take effect until the 1950s when the Delta-Mendota Canal was completed and demands for Friant Division water increased.

Reclamation has contracts to deliver up to 936,631 acre-feet per year of water from the Mendota Pool (including diversions at Sack Dam). CVP exchange and water service contract water is diverted and distributed by four water districts: Central California Irrigation District, Columbia Canal Company, Firebaugh Canal Water District, and San Luis Canal Company. Up to 700,000 acre-feet per year are used to replace San Joaquin River water diverted at Friant Dam. Reclamation also delivers CVP water to the Mendota Pool to satisfy the prior rights of James Irrigation District (45,000 acre-feet per year), Tranquility Irrigation District (34,000 acre-feet per year), and Mendota Wildlife Area (30,000 acre-feet per year), as well as a portion of the water contract for Westlands Water District. The Westlands Water District contract with Reclamation is for 50,000 acre-feet per year from the Mendota Pool.

The current Mendota Dam is a non-Federal facility owned and operated by Central California Irrigation District. The dam is located just downstream from the confluence of the San Joaquin River and Fresno Slough, and forms the Mendota Pool. The pool is generally considered to extend to the south past the Mendota Wildlife Area to the terminus of the James Bypass. SLDMWA

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[6] The structure was originally constructed annually using sand-filled sacks to divert water from the San Joaquin River into Temple Slough (now the Arroyo Canal) during periods of low flow.

maintains the water level in the Mendota Pool so that its contractors and prior water right holders may redivert water imported via the Delta-Mendota Canal.

The SLDMWA maintains the water level in the Mendota Pool so that its contractors and prior water right diverters may redivert imported water. The Mendota Pool is generally less than 10 feet deep and averages about 400 feet wide. The total capacity of the pool is about 8,500 acre-feet. Water quality conditions in the Mendota Pool are the result of interaction between the quantity and quality of inflows from the Delta (via the Delta-Mendota Canal), and intermittent inflows from the San Joaquin River, Fresno Slough, James Bypass, Panoche Creek, and seasonal groundwater pumping to the pool.

Sack Dam is a low-head structure built to direct water released from Mendota Dam into the Arroyo Canal (previously known as Temple Slough). Flows released from Mendota Dam average up to 600 cfs during the irrigation season and about 200 cfs during the nonirrigation season; flows greater than 600 cfs spill over the top of the dam. The Arroyo Canal delivers water to the San Luis Canal Company, National Wildlife Refuges and wetlands in Grassland Water District.

Reach 4: Sack Dam to Bear Creek

Reach 4 extends from Sack Dam to the confluence with Bear Creek. Reach 4 is generally dry throughout the year, except during high-flow events when flow spills over Sack Dam. This spill water is subsequently diverted into the Eastside Bypass at the Sand Slough Control Structure. The Sand Slough Control Structure is designed to route up to 3,000 cfs into the Eastside Bypass and divert 1,500 cfs into the San Joaquin River. Flows have not been diverted into the downstream reach of the San Joaquin River (including during the 1997 flood) because of low conveyance capacity. The Mariposa Bypass Control Structure diverts the first 8,500 cfs of flow from the Eastside Bypass into the Mariposa Bypass and then to the San Joaquin River. Additional flow remaining in the Eastside Bypass travels to Bear Creek and then returns to the San Joaquin River. There are no riparian diversions in Reach 4.

Reach 5: Bear Creek to Merced River

Reach 5 extends from the Bear Creek confluence to the San Joaquin River's confluence with the Merced River. Levees along the river disconnect it from the historical floodplain and network of secondary channels. Tributaries to this stretch of the river include Bear Creek/Eastside Bypass, Salt Slough, and Mud Slough. During the summer months, groundwater inflows to this reach of the river are supplemented by agricultural and wetland return flows. During winter flood flow events, there is inflow from the Eastside Bypass via Mariposa Slough and Bear Creek. A considerable backwater area extends upstream from Salt Slough and Mud Slough to approximately 1 mile upstream from the Lander Road (State Route 165) crossing. There are minor river diversions along this reach.

Reach 6: Merced River to Vernalis Gage

Reach 6 is the lower San Joaquin River from the confluence with the Merced River to the Vernalis gage. Flow in this section of the river is characterized by inflow from tributary streams and rivers, groundwater accretions, and agricultural drainage water.

The Central Valley RWQCB identified 75 pump diversions between the Merced River confluence and Vernalis (1989). Major diverters along this reach of the river are West Stanislaus Irrigation District, Patterson Irrigation District, and El Soyo Water District, all located on the Westside. West Stanislaus Irrigation District is the largest diverter, and also diverts water for the White Lake Mutual Company. Patterson Irrigation District is the second largest diverter. El Soyo Water District, unlike the other two districts, has no contract with Reclamation for CVP water, and therefore relies on San Joaquin River water, supplemented by groundwater pumping.[7] All three districts report river diversions to SWRCB.

Kratzer et al. (1987) estimated the volume of surface water diversions along this reach of the river based on water rights and land use data. Diversions by post-1914 appropriative water right holders were based on the maximum allowable diversion specified in the water right license. Diversions by pre-1914 and riparian water right holders were estimated based on land use and crop water requirements. Kratzer et al. (1987) estimated that the three largest diverters accounted for approximately 50 percent of the total diversion.

In 1991, the California Department of Fish and Game (DFG) initiated a study to inventory water diversions (Janna Herren and Spencer S. Kawasaki, 1991). The initial focus of the study was the Delta and Suisun Marsh, continuing to the Sacramento River and the San Joaquin River basin. The DFG survey documents 19 left-bank and 20 right-bank diversions along the San Joaquin River between the Merced River confluence and Vernalis.

Flow Measurement

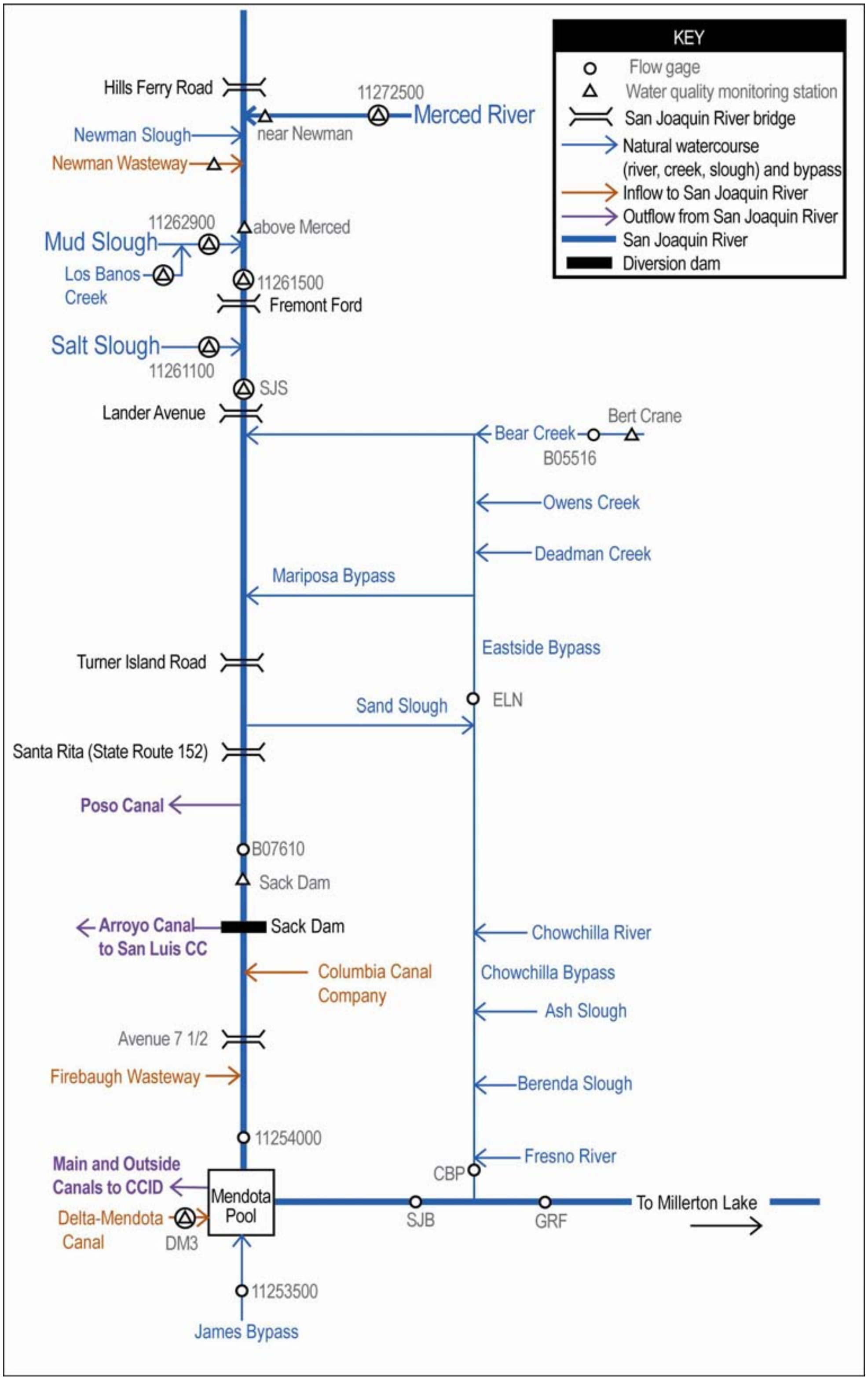
Continuous flow measurement along the San Joaquin River from the Chowchilla Bypass to the river gage at the Airport Way Bridge near Vernalis provides the best data for calibration and validation of the proposed water budget for the study area at a regional scale. The control volume for the San Joaquin River will include westside tributaries and the lower reaches of the eastside tributaries below the most downstream gage locations. Figures 2-1 and 2-2 illustrate components of the water budget along the San Joaquin River. Table 2-1 lists flow gages along the San Joaquin River, and gages on tributaries that will define boundary conditions for the water budget. (Note that ungaged inflows from the eastside of the San Joaquin Valley will be taken directly from the San Joaquin River application of WARMF (SJR-WARMF). No additional analysis or refinement of these flow components will be conducted. The WARMF model is described in Chapter 4.)

[7] In addition to these districts, Banta Carbona Irrigation District diverts water from the San Joaquin River downstream of Vernalis, to irrigate lands located North of the Study Area within the Delta.

Table 2-1. Selected Flow Gages on the San Joaquin River and Tributaries

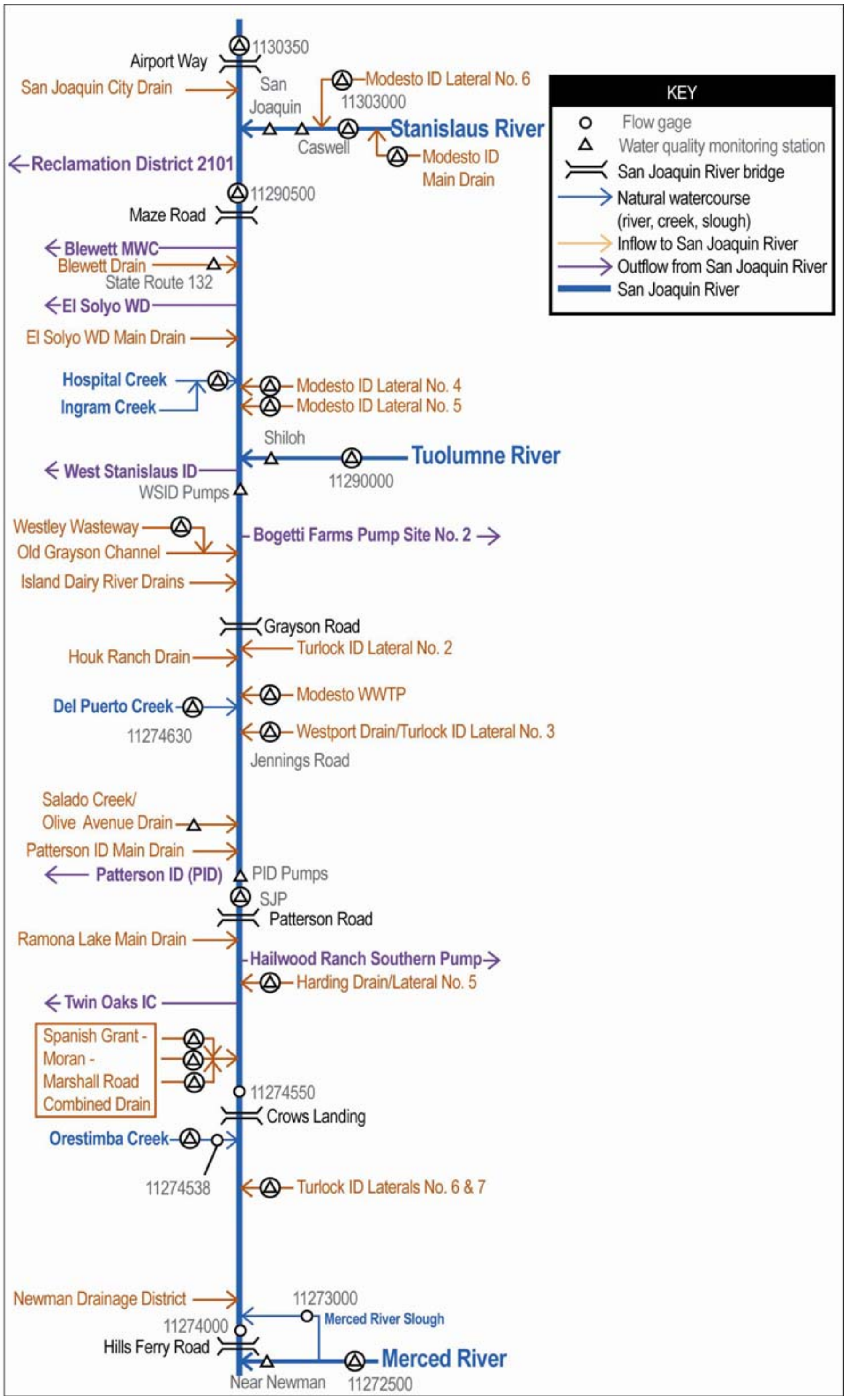
River Reach	Gage Name	Gage Station ID			Period of Record
		USGS	DWR	CDEC	
San Joaquin River – Reach 2: Gravelly Ford to Mendota Pool	San Joaquin River at Gravelly Ford	-	B07770	GRF	10/1974 – 09/2007
	San Joaquin River below Control Structure	-	B07798	SJB	10/1974 – 09/1986 10/1988 – 09/1997 10/2005 – 09/2007
	James Bypass near San Joaquin	11253500	C00200	JBP	10/1974 – 09/1987 10/1995 – 09/1997
	Delta-Mendota Canal Check 21	-	B00770	DM3	
San Joaquin River – Reach 3: Mendota Pool to Sack Dam	San Joaquin River near Mendota	11254000	B07710	MEN	10/1950 – 09/1954 10/1974 – 09/2007
	Sack Dam Gage	-	-	-	Proposed
San Joaquin River – Reach 4: Sack Dam to Bear Creek	Sand Slough Gage	-	-	-	Proposed
San Joaquin River – Reach 5: Sand Slough to Merced	San Joaquin River near Stevinson		B07400	SJS	10/1981 – 09/2007
	Salt Slough at Highway 165 near Stevinson	11261100	B00470	SSH	10/1985 – 09/2007
	San Joaquin River at Fremont Ford Bridge	11261500	B07375	FFB	10/1936 – 09/1971 10/1985 – 09/1989 10/2001 – 09/2007
	Mud Slough near Gustine	11262900		MSG	10/1985 – 09/2007
	Merced River near Stevinson	11272500	B05125	MST	10/1940 – 09/2007
	Merced River Slough near Newman	11273000	B05110	-	10/1941 – 09/1972
San Joaquin River – Reach 6: Merced to Vernalis	San Joaquin River near Newman	11274000	B07300	NEW	10/1911 – 09/2007
	Orestimba Creek at River Road near Crows Landing	11274538		OCL	10/1991 – 09/2007
	San Joaquin River near Crows Landing	11274550	B07250	SCL	10/1995 – 09/2007
	San Joaquin River near Patterson			SJP	01/1984 – 09/2005
	Del Puerto Creek (at Vineyard Road) near Patterson	11274630	B88004		07/1965 – 09/2007
	Tuolumne River at Modesto near Stevenson	11290000	B04120	MOD	10/1939 – 09/2007
	Ingram Creek	-	-	-	
	Hospital Creek	-	-	-	
	San Joaquin River at Maze Road Bridge near Modesto	11290500	B07040	MRB	01/2005 – 12/2005
	Stanislaus River at Ripon	11303000	B03125	RIP	10/1940 – 09/2007
	Airport Way Bridge near Vernalis	11303500	B07020	VNS	10/1923 – 09/1924 10/1929 – 09/2007
Chowchilla/Eastside Bypass	Chowchilla Bypass at head below control structure	-	B07802	CBP	10/1974 – 09/1986 10/1988 – 09/1997
	Eastside Bypass near El Nido	-	B00435	ELN	10/1980 – 09/2007
	Bear Creek below Eastside Canal	-	B05516	-	10/1980 – 09/2007

Key:
- = not applicable
CDEC = California Data Exchange Center
DWR = California Department of Water Resources
USGS = U.S. Geological Survey



Key:
CBP = Chowchilla Bypass at Head below Control Structure
ELN = Eastside Bypass near El Nido
GRF = San Joaquin River at Gravelly Ford
SJB = San Joaquin River below Bifurcation Structure
SJS = San Joaquin River near Stevinson

Figure 2-1. Lower San Joaquin River, Mendota Pool to Merced River



Key:
Dist. = District
IC = Irrigation Company
ID = Irrigation District

No. = Number
SJP = San Joaquin River at Patterson
WWTP = Wastewater Treatment Plant

Figure 2-2. Lower San Joaquin River, Merced River to Airport Way

Lower San Joaquin River Diversions

Table 2-2 summarizes the number and location of water diversions along the San Joaquin River by river reach.

Table 2-2. Surface Water Diversions from San Joaquin River

River Reach	Description	Upstream River Mile	No. of Westside Diversions	No. of Eastside Diversions
1	Mendota Dam to Avenue 71/2	203	0	1
2	Avenue 71/2 to Sack Dam[1]	192	1	0
3	Sack Dam to Santa Rita Bridge (Highway 152)	180	1	0
4	Santa Rita Bridge to Sand Slough Control Structure	173	1	2
5	Sand Slough Control Structure to Turner Island Road	166	0	2
6	Turner Island Road to Mariposa Bypass	157	1	1
7	Mariposa Bypass to Bear Creek	145	1	2
8	Bear Creek to Lander Avenue Bridge (Highway 165)	134	0	0
9	Lander Avenue Bridge to Salt Slough	131	0	1
10	Salt Slough to Fremont Ford Bridge (Highway 140)	127	0	0
11	Fremont Ford Bridge to Mud Slough	123	0	1
12	Mud Slough to Hills Ferry Road Bridge	119	0	0
13	Hills Ferry Road Bridge to Crows Landing Road Bridge	115	3	8
14	Crows Landing Bridge to Patterson Bridge	105	3	5
15	Patterson Bridge to Grayson Road Bridge[2]	96	5	3
16	Grayson Road Bridge to Maze Road Bridge (Highway 132)[3]	87	6	6
17	Maze Road Bridge to Airport Way (Vernalis)	75	3	3

Source: Central Valley RWQCB, 1989

Notes:

[1] San Luis Canal Company diversion at Sack Dam into Arroyo Canal.

[2] Includes diversion by Patterson Irrigation District.

[3] Includes diversions by West Stanislaus Irrigation District and El Soyo Water District.

Lower San Joaquin River Drainage Inflows

In addition to the westside tributaries, stormwater runoff and drainage from irrigated lands and managed wetlands are conveyed via a series of man-made channels to the San Joaquin River. Additionally, Firebaugh, Newman, and Westley wasteways discharge significant operational spills from the Delta-Mendota Canal and tailwater from irrigation. Table 2-3 summarizes the number and location of drainage discharges to the San Joaquin River by river reach. Major Westside drainage inflows and bridges are listed by river mile. Major Westside and Eastside tributaries are listed for reference. Kratzer et al. (1987) report areas of subsurface tile drains that discharge to the San Joaquin River, as listed in Table 2-4.

Subsurface drainage from the Grasslands Drainage Area is conveyed via the San Luis Drain to Mud Slough (North). The Grasslands Drainage Area includes Firebaugh Canal Water District, Panoche Water District, Pacheco Water District, and parts of San Luis Water District and Central California Irrigation District. Panoche Drainage District provides drainage service to Panoche, Oro

Lomo, Eagle Field, and Mercy Springs water districts[8]. Broadview and Widren water districts lie within the Grasslands Drainage Area but are no longer irrigated and do not contribute drainage to the Grassland Bypass Channel. Charlestown Drainage District consists of lands in San Luis Water District and Central California Irrigation District (4,275 acres and 500, acres respectively). Camp 13 Drainage District is an association of landowners within Central California Irrigation District.

[8] Note that drainage areas are based on natural and manmade drainage pathways for each watershed or catchment area; whereas water service areas are jurisdictional boundaries for providing irrigation and municipal water supplies.

Table 2-3. Discharges to San Joaquin River

River Reach	Location and Description of Major Discharges	Upstream River Mile	Westside Inflows[3]	Eastside Inflows[3]
1	Mendota Dam to Avenue 71/2 Firebaugh Wasteway	203	2	1
2	Avenue 71/2 to Sack Dam Columbia Canal Company return flows	192	1	3
3	Sack Dam to Santa Rita Bridge (Highway 152)	180	0	0
4	Santa Rita Bridge to Sand Slough Control Structure	173	1	1
5	Sand Slough Control Structure to Turner Island Road	166	1	0
6	Turner Island Road to Mariposa Bypass	157	0	2
7	Mariposa Bypass to Bear Creek	145	2*	11*
8	Bear Creek to Lander Avenue Bridge (Highway 165) **Bear Creek**	134 **134**	0*	4*
9	Lander Avenue Bridge to Salt Slough	131	0*	0*
10	Salt Slough to Fremont Ford Bridge (Highway 140) **Salt Slough**	127 **127**	1	3*
11	Fremont Ford Bridge to Mud Slough	123	0	0*
12	Mud Slough to Hills Ferry Road Bridge **Mud Slough** Newman Wasteway Newman Slough **Merced River**	119 **119** **116**	4	1*
13	Hills Ferry Road Bridge to Crows Landing Road Bridge Newman Drainage District **Orestimba Creek**	115 **106**	10	3
14	Crows Landing Bridge to Patterson Bridge Spanish Grant – Moran Road Combined Drain Ramona Lake Main Drain	105	5	4
15	Patterson Bridge to Grayson Road Bridge Patterson Irrigation Main Drain Olive Avenue Drain **Del Puerto Creek** Houk Ranch Drain	96 **91**	14	3
16	Grayson Road Bridge to Maze Road Bridge (Highway 132) Island Dairy River Drain Old Grayson Channel **Tuolumne River** Ingram – Hospital Combined Outfall El Soyo Water District Main Drain Blewitt Drain	87 **81**	14	9
17	Maze Road Bridge to Airport Way (Vernalis) **Stanislaus River** San Joaquin City Drain	75 **72**	1	3

Source: Central Valley RWQCB, 1989
Notes:
[1] Major tributaries are shown in bold
[2] "*" indicates that numerous flood gates are located along this section of the river
[3] Based on survey data presented in SWRCB (1989) Add river mile and Westley Drain

Table 2-4. Subsurface Agricultural Drainage

Tiled Area (acres)	Point of Discharge	River Mile
600	Newman Drainage District – Collector Line A	119.0
2,500	Newman Drainage District – Collector Line A	119.0
1,550	Spanish Grant – Moran Road Combined Drain	105.0
1,360	Ramona Lake Drain	100.0
1,650	Patterson Irrigation District Main Drain	101.5
350	Richie Slough Main Drain	91.5
1,350	Hospital Creek – Haggerman Ranch Drain	79.9
250	El Solyo Water District – Hetch Hetchy Drain	77.6
400	McCracken Road Drain	73.0

Westside Tributaries

The flow in the main stem of the San Joaquin River from Bear Creek to Vernalis is supplemented by a large number of ephemeral streams that convey stormwater runoff from the Coast Range in the winter, and contain mostly agricultural runoff and drainage during the summer months. Westside tributaries along the main stem of the San Joaquin River may represent 16 percent of the San Joaquin River flow at Vernalis (Quinn and Tulloch, 2002). From north to south, these creeks include Hospital and Ingram creeks, Del Puerto Creek, Orestimba Creek, Garzas Creek, Quinto Creek, Los Banos Creek, and Panoche and Silver creeks. Water in Garzas and Quinto creeks is diverted into the Central California Irrigation District Main Canal. Outflow from other westside watersheds mostly infiltrates into the ground before reaching the San Joaquin River.

Hospital and Ingram Creeks

Hospital and Ingram creeks combine to the east of Highway 33. The combined flow from the ungaged watersheds runs through West Stanislaus Irrigation District before discharging to the San Joaquin River at River Mile (RM) 75. The combined outfall discharges stormwater runoff originating from the Hospital and Ingram creek watersheds, agricultural drainage (including 2,300 acres of tile drain flows), and outflow from the White Lake Mutual – Hagemann Ranch Main Drain and Hagemann Ranch Southern Main Drain.

Del Puerto Creek

Del Puerto Creek drains from Del Puerto Canyon, and flows through West Stanislaus Irrigation District into the San Joaquin River just north of the City of Patterson, at RM 92. Flow in Del Puerto Creek is highly seasonal, with highly flashy flows during the storm season, and is dominated by agricultural return flows during the dry season.

Orestimba Creek

Orestimba Creek is the dominant Westside tributary and can produce substantial and sustained flows after prolonged precipitation. The creek flows into the San

Joaquin River just south of the City of Patterson at RM 107. Similar to Del Puerto Creek, flows are highly flashy during the wet season. During the dry season, flows are dominated by agricultural drainage; the majority of inflow originates from the Central California Irrigation District Main canal, which spills into Orestimba Creek approximately 2 miles upstream from the creek's confluence with the San Joaquin River.

Garzas Creek

Garzas Creek is located roughly 2 miles south of the town of Gustine. The creek is used to distribute water from the Central California Irrigation District Main Canal to north Grassland Water District. The creek does not convey drain water.

Quinto Creek

The Quinto Creek watershed is relatively small and of only minor significance.

Los Banos Creek

Los Banos Detention Dam and Reservoir provide flood protection for the California Aqueduct, Delta-Mendota Canal, and City of Los Banos. The reservoir has a maximum operational storage of 34,560 acre-feet. From September to May, 14,000 acre-feet of space are maintained for flood control. Los Banos Creek merges with Mud Slough (north) before discharging to the San Joaquin River at RM 127.

Mud Slough (North)

Mud Slough (North) is one of the major west-side tributaries of the San Joaquin River, and also conveys drainage water from the Grasslands Drainage Area to the San Joaquin River. Flows are highly variable throughout the year, ranging from high flow during the wet season and during periods of wetland releases to very low flow during the summer and early fall.

Agricultural drainage from the selenium-affected area of the Grasslands Basin, conveyed through San Luis Drain, is discharged into Mud Slough at a point about 6 miles upstream from the slough's confluence with the San Joaquin River. Flow in Mud Slough upstream from this discharge point consists of wetland releases from Grasslands Water District and Volta Wildlife Management Area, operational spills from the Delta-Mendota Canal and the Central California Irrigation District Main Canal, and stormwater runoff from Los Banos Creek. Mud Slough downstream from the San Luis Drain discharge point is often dominated by water originating from the Grasslands Drainage Area. Flow from San Luis Drain accounts for 20 to 40 percent of the annual flow in Mud Slough (North). USGS maintains a flow gaging station (11262900 – CalSim 3.0 node MSN008) 0.6 miles downstream from the San Luis Drain discharge point.

Salt Slough

Salt Slough conveys a mix of agricultural drainage and wetland return flow. It merges with Mud Slough (South) before discharging to the San Joaquin River at

RM 127. Before initiation of the Grasslands Bypass Project in 1996, Salt Slough carried selenium-contaminated water. Subsurface drainage water from Panoche, Pacheco, Widren, Broadview, and Firebaugh water districts was combined in the Main Drain, a conveyance facility that runs parallel to the Central California Irrigation District Main Canal, and discharged through Camp 13 and Agatha canals to Mud Slough (South). From Mud Slough south, drainage flows were diverted through the Blake-Porter Bypass to Salt Slough. After the Grasslands Bypass Project was implemented, Salt Slough has carried a blend of wetland discharges, operational spills, and agricultural return Flows from areas outside the Grasslands Drainage Area (Quinn and Tulloch, 2002). USGS maintains a flow gaging station on Salt Slough at State Highway 165 near Stevinson (USGS 11261100).

Panoche-Silver Creek

This watershed lies on the southern boundary of the San Joaquin River basin. During and after sustained precipitation such as occurred in 1995 and 1997, considerable runoff is generated within the watershed flood flows move east along Belmont Avenue into the town of Mendota, discharging directly into the Mendota Pool.

Central Valley Project Agricultural Contractors

The CVP Agricultural Contractors are comprised of agricultural lands that hold CVP water contract entitlements with diversion of waters directly from the Delta-Mendota Canal and the Mendota Pool. The three primary CVP service areas are comprised of the Upper Delta-Mendota Canal, Lower Delta-Mendota Canal and Mendota Pool service areas. Additional CVP contractors share diversions with the State Water Project contractors along the Joint Reach of the California Aqueduct.

Upper Delta-Mendota Canal Service Area

Check 13 on the Delta-Mendota Canal, just upstream from the O’Neill Pumping-Generating Plant, marks the division between the upper and lower canal service areas. CVP contractors receiving deliveries from the Delta-Mendota Canal upstream from Check 13 include the following: (Note that listed items are in order of delivery points along the Delta-Mendota Canal from north to south.)

- Byron Bethany Irrigation District (only the former Plainview Irrigation District is located within the study area)
- City of Tracy (located outside the study area)
- Banta Carbona Irrigation District (located outside the study area)

- Westside Irrigation District (almost entirely located outside the study area)
- West Stanislaus Irrigation District
- Patterson Irrigation District
- Del Puerto Water District

Del Puerto Water District was reorganized in 1995, through a formal consolidation with 10 other districts (Hospital, Kern Canon, Salado, Sunflower, Orestimba, Foothill, Davis, Mustang, Quinto, and Romero water districts). The reorganized Del Puerto Water District is located on both sides of the Delta-Mendota Canal and consists of a narrow strip of land averaging less than 2 miles in width and stretching 50 miles in length.

Lower Delta-Mendota Canal Service Area

CVP Contractors receiving water from the Delta-Mendota Canal downstream from Check 13 include the following:

- Laguna Water District
- Eagle Field Water District
- Mercy Springs Water District
- Oro Loma Water District
- Firebaugh Canal Company
- San Luis Water District
- Panoche Water District
- Pacheco Water District

Eagle Field, Mercy Springs, Oro Loma, Panoche, and Pacheco water districts and the Firebaugh Canal Company lie within the Grasslands Drainage Area. Part of San Luis Water District is also located within the Grasslands Drainage Area. Broadview and Widren water districts also lie within the Grasslands Drainage Area but are no longer irrigated and do not contribute drainage to the Grasslands Bypass Channel.

Mendota Pool Service Area

Water from the Mendota Pool is delivered to the following CVP contractors:

- Laguna Water District
- Central California Irrigation District (partly located within the Grasslands Drainage Area)
- San Luis Canal Company

- Firebaugh Canal Company (located within the Grasslands Drainage Area)
- Columbia Canal Company
- Coelho Family Trust (located outside the study area)
- Fresno Slough Water District (located outside the study area)
- James Irrigation District (located outside the study area)
- Reclamation District 1606 (located outside the study area)
- Tranquility Irrigation District (located outside the study areA)
- Tranquility Public Utility District (located outside the study area)
- Westlands Water District (located partly outside the study area)
- Mendota Wildlife Area (located outside the study area)

Laguna Water District has no distribution facilities of its own. Water released from the Delta-Mendota Canal into the Mendota Pool is subsequently transported from the pool through the distribution facilities of the Central California Irrigation District to the Laguna Water District.

California Aqueduct – Joint Reach Service Area

CVP contractors receiving water from the Joint Reach of the California Aqueduct include San Luis District, Pacheco Water District, Panoche Water District, and Westlands Water District. Westlands Water District is located partly outside the study area.

About 200,000 acres within the San Luis District, referred to as the Direct Service Area, receive water from 39 turnouts on the Delta-Mendota Canal and 23 turnouts on the San Luis Canal. In addition to the Direct Service Area, three improvement districts are also served through distribution systems branching off the Joint Reach of the California Aqueduct. Pacheco Water District is supplied from the San Luis Canal, with the Delta-Mendota Canal serving as a backup source. The Pacheco Water District also has a surface water supply from the Central California Irrigation District, under a Railroad Commission Order authorizing service to Pacheco Water district. Panoche Water District obtains CVP water through two diversion points on the Delta-Mendota Canal and five diversion points on the San Luis Canal.

Westlands Water District is located between the coastal range and the trough of the San Joaquin Valley in the Tulare Lake hydrologic region. When the district was originally organized, it included approximately 376,000 acres. In 1965, Westlands Water District merged with its western neighbor, Westplains Water Storage District, adding 210,000 acres. Additionally, lands comprising about 18,000 acres were annexed to the district after the merger to form the current 604,000-acre district. The district has three distinct water service areas. Priority Area I covers the original lands; the Westplains area is referred to as Priority Area II. Priority Area III is land added to the district after the merger and has no established water allocation. Most of Priority Area I is located east of the San Luis Canal and has gravity water service. Much of Priority Area II is west and upslope from the San Luis Canal, and is served by pumping from the San Luis Canal and gravity supply from the Coalinga Canal. Westlands Water District Distribution Districts No. 1 and 2 were formed from lands within the Westlands Water District for the purpose of entering into assignment contracts with Reclamation.

Managed Wetlands

Table 2-5 summarizes managed wetlands located within the study area. These include National Wildlife Refuges and Wildlife Management Areas managed by the U.S. Fish and Wildlife Service (USFWS), wildlife areas managed by CDFG, and private wetlands and duck clubs within Grasslands Water District. With the exception of the Mendota Wildlife Management Area,[9] these wetlands lie within the Grasslands Ecological Area (GEA), which encompasses 160,000 acres, or nearly 300 square miles of wetlands that have survived major water diversions, urban encroachment, and agricultural development.

Federal refuges include the Kesterson, Freitas, West Bear Creek, and San Luis units of the San Luis National Wildlife Refuge. State wildlife areas include Volta Wildlife Management Area, Los Banos Wildlife Management Area (which lies within Grassland Water District), and the North Grassland Wildlife Management Area which consists of the China Island, Salt Slough and Gadwall units. Grassland Water District contains approximately 203 separate ownerships, most of which are hunting or duck clubs. Grassland Water District was established in 1953 as a legal entity for contracting with Reclamation to receive CVP water. It is composed of two separate geographical areas, commonly referred to as North Grasslands and South Grasslands.

The CVPIA, signed in 1992, altered management of the CVP to make fish and wildlife protection, restoration, and enhancement project purposes having equal priority with agriculture, M&I, and power uses. As part of Section 3406(d) of the CVPIA, Central Valley Refuges and Wildlife Habitat Areas, Reclamation signed long-term water supply contracts and agreements and memorandums of understanding to provide long-term water supplies (up to 25 years) to specified Federal National Wildlife Refuges, State Wildlife Management Areas, and

[9] The Mendota Wildlife Management Area is located outside the study area, but is included here because it diverts from the Fresno Slough/Mendota Pool.

private wetlands in the Grasslands Resource Conservation District. The CVPIA adopted by reference dependable water supplies from the *Report on Refuge Water Supply Investigations, Central Valley Hydrologic Basin, California* (Reclamation, 1989) as specific quantities of water to be provided to the refuges. Historical average water supplies are defined as “Level 2” supplies. Incremental “Level 4” water supplies are the additional water required to achieve optimum waterfowl habitat management. Reclamation, in partnership with USFWS, has developed a Water Acquisition Program to provide Level 4 refuge water supplies. The Water Acquisition Program goal is to acquire up to 163,000 acre-feet annually (133,264 acre-feet of Level water 4, and 26,007 acre-feet of replacement water).

Table 2-5. Managed Wetlands Within the Study Area

Refuge/Wildlife Management Area	Area (acres)	Managed by	Water Source		Point of Diversion
			GW	SW	
Volta WA	2,889	DFG[1]		√	Delta-Mendota Canal via Volta Wasteway, CCID Main Canal
Kesterson Unit of San Luis NWR	5,900	USFWS	√	√	Grassland Water District via San Luis Canal, Santa Fe Canal, and Fremont Canal
Freitas Unit of San Luis NWR	5,600	USFWS	√[2]	√	Grassland Water District via San Luis Canal, Santa Fe Canal, and Fremont Canal
China Island Unit of North Grassland WA	3,315	DFG	√	√	Central California Irrigation District via J Lateral
Blue Goose Unit of San Luis NWR	N/A.	USFWS		√	Grassland Water District via San Luis Canal, Santa Fe Canal, and Fremont Canal
San Luis Unit of San Luis NWR	7,430	USFWS		√	San Luis Canal Company via island C Canal, Salt Slough
West Bear Creek Unit of San Luis NWR	3,892	USFWS	√	√	San Luis Canal Company via island C Canal
Los Banos WA	5,586	DFG	√	√	San Luis Canal Company via San Pedro Canal, West Delta Canal, Grassland Water District Boundary Drain, and Salt Slough upstream from the Mud Slough (South) confluence Grassland Water District via San Luis Canal
Gadwall Unit of North Grassland WA	305	DFG		√	N/A
Salt Slough Unit of North WA	2,241	DFG	√	√	Grassland Water District via San Luis Canal
Grassland Water District - North	30,000	Private		√	Delta-Mendota Canal via Volta Wasteway, CCID Main Canal
Grassland Water District - South	20,500	Private		√	Central California Irrigation District via Main Canal, Arroyo Canal, and San Pedro Canal
Mendota WA	12,425	DFG		√	Mendota Pool via Fresno Slough

Notes:
[1] Although owned by Reclamation, the Wildlife Management Area has been leased to and managed by DFG since its creation in 1952.
[2] Drought period supply.
Key:
N/A = not available
CCID = Central California Irrigation District
DFG = California Department of Fish and Game
GW = groundwater
NWR = National Wildlife Refuge
SW = surface water
USFWS = U.S. Fish and Wildlife Service
WA = Wildlife Management Area

Municipal Water Use

Urban development within the study area consists of small cities and towns that mostly rely on groundwater. The exception is the City of Dos Palos, which receives some raw water deliveries from the California Aqueduct. The City of Tracy is the largest community in the Westside Region of the San Joaquin Valley, but lies north of the study area. Based on DWR's water use estimates for the *California 2009 Water Plan Update* (DWR, 2009), per capita water use for the towns of Dos Palos, Gustine, Los Banos, and Newman range from 200 to 240 gallons per capita per day (gpcd), with a total annual use of approximately 13,000 acre-feet. Urban water use is not a significant component of the Westside water budget.

Groundwater

Groundwater underlying the alluvial portion of the study area occurs within the Tracy and Delta-Mendota subbasins (DWR, 2003). The Corcoran Clay layer divides the groundwater system into two major aquifers: an upper semiconfined aquifer above the clay layer, and a confined aquifer below the clay layer (Williamson et al., 1989). The Corcoran Clay layer occurs throughout all but the eastern and western margins of the San Joaquin Valley at about 300 feet below sea level. Above the Corcoran Clay layer, three main hydrogeologic categories are defined: Coast Range alluvium (derived from marine deposits rich in salts), Sierran sand (medium- and coarse-grained fluvial deposits from the Sierra Nevada to the east), and flood-basin deposits (silt and clay deposits overlying the Sierran sand). Natural recharge of the upper aquifer occurs from stream seepage, deep percolation of precipitation, and subsurface inflow along basin boundaries. This natural recharge is augmented by deep percolation of irrigation water, seepage from permanent and semipermanent managed wetlands, and seepage from conveyance and distribution canal systems. Recharge of the lower confined aquifer is primarily from subsurface inflow from the valley floor and foothill areas beyond the eastern boundary of the Corcoran Clay layer. The Corcoran Clay layer is not continuous in some areas, and some seepage from the semiconfined aquifer above does occur through the confining layer.

Outflows from the groundwater aquifers include capillary rise into the root zone and associated evaporation/ETo, subsurface drainage, inflow to Westside tributaries and the San Joaquin River, and lateral groundwater flow eastward under the San Joaquin River.

The semiconfined aquifer above the Corcoran Clay is fully saturated in much of the study area, with water tables within 5 feet of the ground surface. The combination of imported salts from irrigation water and irrigation-induced leaching of the soil profile has degraded water quality in the upper portion of the semiconfined aquifer. Water quality improves with depth. Groundwater extractions for agricultural purposes are from private wells; there are no district-owned groundwater wells. Within the Grasslands Drainage Area, Firebaugh Canal Company and Central California Irrigation District both pump from the shallow water table to reduce subsurface drainage. Groundwater pumping below the Corcoran Clay layer is limited because of concerns about land subsidence. In the Northwest Subarea, pumping is limited in areas away from the river because of higher energy costs in pumping water from greater depths.

Chapter 3
Analytical Approach

This chapter discusses the approach to establishing a set of volumetric water budgets for the study area. Conceptually simple, these water budgets assess inflows and outflow across a three-dimensional control volume, and changes in storage within the control volume. Changes in storage include detention storage of precipitation, changes in soil moisture, changes in groundwater storage, and storage of surface water in permanent and seasonal wetlands. Many components of the water budgets must be determined indirectly because observed gage data are limited, particularly for the Northwest Subarea where the modes of water use, storage, and reuse are uncertain from year to year.

Control Volume

Volumetric water budgets will be developed for four control volumes using a mix of spreadsheets, a watershed model, and an IWFM. Although the water budgets are described separately, they are closely interlinked. Combined, the water budgets will account for flows throughout the study area.

California Aqueduct, Delta-Mendota Canal, and San Luis Reservoir

Water budgets will be developed for the California Aqueduct and Delta-Mendota Canal to better understand how canal operations and filling and draining San Luis Reservoir influence salinity of water deliveries to CVP Contractors within the study area. For the California Aqueduct, the control volume will stretch from Harvey O. Banks Pumping Plant (Banks Pumping Plan) in the Delta to Check 21, located at the end of the Joint Reach (San Luis Canal). The aqueduct water budget will consider the interchange of water with San Luis Reservoir at the O’Neill Forebay through the Gianelli Pumping/Generating facility, and the interchange of water with the Delta-Mendota Canal through the O’Neill Pumping/Generating facility.

The control volume for the Delta-Mendota Canal will include the entire length of the canal. The water budget will account for water deliveries, groundwater pump-ins, inflow from stormwater runoff, and canal seepage losses.

Land Surface Topology and Root Zone

The second control volume consists of the land surface within the study area and the underlying root zone. Inflows to the control volume consist of CVP and SWP deliveries, precipitation, groundwater inflow to drains (including subsurface drainage) and Westside tributaries, capillary rise, and groundwater pumping. Outflows consist of evaporation and ETo, tributary and surface drainage flows to the San Joaquin River, and deep percolation from the root zone to the underlying aquifer.

San Joaquin River

The control volume for the San Joaquin River includes the Mendota Pool and reach of the river between Mendota Dam and Vernalis. The control volume will be subdivided into shorter river reaches based on flow gage stations. Inflows to the river include stormwater runoff, agricultural surface and subsurface drainage, managed wetland releases, and groundwater accretion. Outflows are predominantly agricultural surface water diversions. Inflows and outflows from the Eastside of the San Joaquin River will be taken from previous modeling work conducted for the determining control measures to meet the San Joaquin River dissolved oxygen total maximum daily load (TMDL) and the Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) pilot studies (Larry Walker and Assoc., 2010).

Groundwater

The fourth control volume will consider groundwater underlying the study area. The groundwater budget will validate groundwater recharge and groundwater pumping rates as well as determine the surface water budget, and provide estimates of groundwater inflow to the San Joaquin River from the Westside Region.

Temporal Scale

In general, all water budgets will be developed and presented at a monthly timestep. However, various components of the water budget require a finer timescale. For example, estimates of stormwater runoff will be developed from daily precipitation records. Similarly, baseflow separation of flow data will be performed using a daily timestep.

Spatial Scale

The spatial resolution of the analysis is determined to facilitate the use of available flow and water quality gage data for model calibration and validation. Spatial resolution of the analysis is also chosen to honor, as far as possible, the resolution of available input data. Distributed land use, land cover, and soils data are available at field scale. Daily meteorological data are point data, although distributed grids of precipitation and ET averaged over a longer timestep are available. CVP delivery data are contractor-based. San Joaquin River diversion data are available for the larger water districts.

In general, the proposed geographic extent of the analysis coincides with the study area, which is consistent with the subareas defined by Central Valley

RWQCB. However, the spatial extent of the selected groundwater model (discussed later) extends outside the limits of the study area.

For the valley floor, the spatial unit for analysis is determined by the intersection of water district boundaries with drainage area boundaries. Most districts will be treated as a single unit. Water budgets presented at a district scale will facilitate understanding of water and salt transport at a local level, and options to manage salt loading to the San Joaquin River. Proposed spatial units are presented in Table 3-1.[10] Within the Coast Range, water budget units will be delineated by watershed.

Time Period

Water budgets will be developed for the period of October 1999 to September 2007. This period is defined to limit analysis to a time frame that coincides with current management and operations of the Grasslands Bypass Project, and by the availability of data. The Westside Salt Assessment will initially focus on 2 years within this period to limit the amount of work required for groundwater model calibration (discussed later in Chapter 6). Table 3-2 presents a range of parameters that characterize water years 2000 to 2007. The initial focus of the water budget will be water years 2006 and 2007 (see shaded columns in Table 3-2).

[10] The spatial units (or subregions) identified in the table are being refined as part of the study effort and will be updated in aerial extent and name as part of Task 2 (Westside Region Water Budget) and Task 7 (Model Refinement) deliverables.

Table 3-1. Water Budget Subregions

Subregion	WestSim ID	Surface Water Source	CVP Contract Amount (acre-feet/year)				
			Water Service	Water Right	Exchange	Refuge Level 2	Refuge Level 4
San Joaquin/Stanislaus Unincorporated	5	SJR	-	-	-	-	-
Hospital Water District	6	DMC	34,105	-	-	-	-
West Stanislaus Irrigation District	7	DMC/SJR	50,000	-	-	-	-
El Soyo Water District	8	SJR	-	-	-	-	-
Kern Canyon Water District	9	DMC	7,700	-	-	-	-
Patterson Water District	10	DMC/SJR	16,500	6,000	-	-	-
Del Puerto Water District	11	DMC	12,060	-	-	-	-
Salado Water District	11/13	DMC	9,130	-	-	-	-
Central California Irrigation District (North)	12	DMC	-	-	140,000	-	-
Sunflower Water District	13	DMC	16,625	-	-	-	-
Stanislaus/Merced Unincorporated	14	SJR	-	-	-	-	-
China Island Unit – North Grasslands Wildlife Area	14	DMC	-	-	-	6,967	3,483
Orestimba Water District	15	DMC	15,860	-	-	-	-
City of Los Banos	16	-	-	-	-	-	-
Foothill Water District	17	DMC	10,840	-	-	-	-
Davis Water District	18	DMC	5,400	-	-	-	-
Kesterson Unit – San Luis NWR	19	DMC	-	-	-	10,000	0
West Bear Creek – San Luis NWR	20	DMC	-	-	-	7,207	3,603
Freitas Unit – San Luis NWR	20	DMC	-	-	-	5,290	0
Grasslands Water District (North)	21	DMC	-	-	-	125,000	55,000
Mustang Water District	22	DMC	14,680	-	-	-	-
San Luis Unit – San Luis NWR	23	DMC	-	-	-		19,000
San Luis Canal Company	24	DMC	-	-	163,600	-	-
Salt Slough Unit – North Grasslands Wildlife Area	25	DMC	-	-	-	6,680	3,340
Quinto Water District	26	DMC	8,620	-	-	-	-
Lansdale Water District	27	DMC	CVP contract not renewed				
Los Banos Wildlife Area	28	DMC	-	-	-	16,670	8,330
Volta Wildlife Area	29	DMC	-	-	-	13,000	3,000
Centinella Water District	30	DMC	CVP contract transferred to Westlands Water District				
Romero Water District	31	DMC	5,190	-	-	-	-

Table 3-1. Water Budget Regions (Contd.)

Subregion	WestSim ID	Surface Water Source	CVP Contract Amount (acre-feet/year)				
			Water Service	Water Right	Exchange	Refuge Level 2	Refuge Level 4
Central California Irrigation District (South)	32	DMC/MP	-	-	392,400	-	-
CCID – Charlestown Drainage District			-	-		-	-
San Luis Water District (North)	33	DMC	65,000	-	-	-	-
Grasslands Water District (South)	34	DMC/MP	-	-	-	-	-
Eagle Field Water District – CCID Contracts	35	DMC	-	-	-	-	-
San Luis Water District (South)	36	SLC	60,080	-	-	-	-
SLWD – Charleston Drainage District				-	-	-	-
Panoche Water District	37	DMC/SLC	94,000	-	-	-	-
Eagle Field Water District	38	DMC	4,550	-	-	-	-
Pacheco Water District	39	DMC/SLC	10,080	-	-	-	-
Mercy Springs Water District	40	DMC	2,840	-	-	-	-
Oro Loma Water District	41	DMC	4,600	-	-	-	-
Firebaugh Canal Company	42/44	DMC/MP	-	-	85,000	-	-
Widren Water District	43	-	CVP contract transferred to Westlands Water District				
Broadview Water District	45	-	CVP contract transferred to Westlands Water District				
Westlands Water District (Northeast)	46	SLC/MP	1,234,188	-	-	-	-
Westlands Water District (Northwest)	48	-		-	-	-	-
Columbia Canal Company	N/A	MP	-	-	59,000	-	-
Oak Flat Water District	N/A	CA	-	-	-	-	-

Notes:

[1] WestSim subregions 1 through 4 lie outside the Study Area and are not included in this table.

[2] WestSim subregions 47 through 63 lie outside the Study Area and are not included in this table.

[3] Contract amount for Westlands Water District and associated Distribution Districts comprises 1,200,000, 2,500 from Centinella Water District, 27,000 acre-feet from Broadview water district, 4,198 acre-feet from Mercy Springs Water District, 2,990 acre-feet from Widren Water District

[4] Subregions may include non-district lands adjacent to district lands

[5] Widren Water District and Firebaugh Canal Company will be represented by a single subregion.

[6] The San Joaquin River Improvement Project associated within the Grasslands Drainage Area comprises Mercy Springs Water District and the part of Eagle Field Water District that has water supply contracts with Central California Irrigation District

[7] Level 2 supplies includes replacement water. Without replacement water San Luis (13,350), Kesterson (3,500), Freitas (3,527), Volta (10,000)

Key:

- \- = zero value or no source of supply
- CA = California Aqueduct
- CCID = Central California Irrigation District
- CVP = Central Valley Project
- DMC = Delta-Mendota Canal
- MP = Mendota Pool
- N/A = Not applicable
- NWR = National Wildlife Refuge
- SJR = San Joaquin River
- SLC = San Luis Canal
- SLWD = San Luis Water District

Table 3-2. Water Year Parameter Data

Parameter/Water Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
Runoff/Inflows									
Sacramento Valley Runoff[1] (MAF)	18.9	9.81	14.6	19.31	16.04	18.55	32.09	10.28	N/A
San Joaquin Valley Runoff[1] (MAF)	5.9	3.18	4.06	4.87	3.81	9.21	10.44	2.51	N/A
James Bypass[2] (TAF)	0.0	0.0	0.0	0.0	0.0	60.5	612.1	No data	0.0
San Joaquin River below Friant Dam[3] (TAF)	176.6	132.2	114.0	121.5	116.5	713.8	1,370.1	151.5	141.3
Climate									
Precipitation	8.4	8.8	5.8	9.1	8.7	15.8	10.6	3.9	6.2
Evapotranspiration, Los Banos (inches)		57.8	56.5	55.3	60.3	51.9	53.1	57.7	61.0
Water Year-Type									
Sacramento Valley Index[1]	Above-Normal	Dry	Dry	Above-Normal	Below-Normal	Above-Normal	Wet	Dry	Critical
San Joaquin Valley Index[1]	Above-Normal	Dry	Dry	Below-Normal	Dry	Wet	Wet	Critical	Critical
South-of-Delta Allocations[4]									
Agricultural Contractors (%)	65	49	70	75	70	85	100	50	40
M&I Contractors (%)	90	77	95	100	95	100	100	75	75
CVP Pumping									
Jones Pumping Plant (TAF)	2,487	2,332	2,505	2,685	2,722	2,679	2,628	2,679	2,018
Banks Pumping Plant (TAF)	3,692	2,635	2,900	3,458	3,251	3,625	3,527	2,954	1,527
South-of-Delta Deliveries[5]									
Agricultural Contractors (TAF)	1,397	1,181	1,327	1,404	1,332	1,507	1,563	1,138	843
M&I Contractors (TAF)	10	12	12	13	14	14	16	18	18
Exchange Contractors (TAF)	778	761	780	767	825	769	776	708	714
Refuges, duck clubs, and wildlife areas (TAF)	345	312	336	392	393	296	319	319	282
CVP San Luis Reservoir Storage									
High-point (TAF)	965	1,050	895	969	951	966	969	778	862
Low-point (TAF)	359	245	176	258	90	378	402	83	37
Irrigated Land Index (acres)	N/A	784	825	832	842	839	807	784	N/A

Sources

1 DWR, 2009

2 USGS, 2010a

3 USGS, 2010b

4 Reclamation, 2004

5 Reclamation, 2010

General Notes:

1 CVP south-of-Delta delivery allocation refers to the contract year beginning in March of the corresponding water year.

2 CVP south-of-Delta deliveries are for CVP contract year, rather than water year.

3 Irrigated land index is a partial measure of crop acreage; data are limited to CVP contractors who reported acreage for all water years, from 2000 to 2007.

Key

CVP = Central Valley Project
M&I = municipal and industrial
MAF = million acre-feet
N/A = Not applicable
TAF = thousand acre-feet

Chapter 4
Modeling Tools

Various modeling tools will be used to develop the water budgets, as follows:

- Westside Simulation Model (WestSim)
- WARMF
- IWFM Demand Calculator
- Spreadsheet-based models

WestSim is an application of IWFM Version 3.01 (DWR, 2008) of the entire CVP service area on the Westside of the San Joaquin Valley, including the Tulare Lake Hydrologic Region. This model will be the primary engine and accounting tool for proposed water budgets relating to the land surface, root zone, and underlying groundwater. Using the output capabilities of IWFM, WestSim is configured to output detailed water budgets for each of the water districts and Federal and State wildlife refuges within the study area. Additionally, the WestSim model domain covers the drainage area of Fresno Slough and CVP contractors and water right holders located south of the Mendota Pool. WestSim's simulation of the total water cycle along the Westside will provide a better understanding of irrigation practices and disposition of applied water, use of return flows, groundwater fluxes into and out of subregions and the model domain, and flow boundary conditions to SJR-WARMF (i.e., small tributary stream flows, subsurface groundwater movement vertically and horizontally, and overland flows to the San Joaquin River).

The primary use of SJR-WARMF is to develop salt and nitrate budgets for the Westside Salt Assessment. Although spreadsheet-based tools could be used to compute the salt and nitrate budgets based on output from WestSim, determination of nitrate fluxes requires a more sophisticated approach. Selection of WARMF provides consistency with the approach adopted for the CV-SALTS pilot studies (Larry Walker and Assoc., 2009), and will be an enhanced tool capable of simulating flow and salt and nitrate transport for the entire San Joaquin River Hydrologic Region. As part of the land surface/root zone water budget, SJR-WARMF will be used to disaggregate monthly flow budgets determined by WestSim to a daily timestep. SJR-WARMF will also provide an independent check on WestSim's surface water accounting for small watershed boundary inflows and in-model river and streamflows.

The IWFM Demand Calculator and spreadsheet tools will address identified weaknesses in WestSim and WARMF that cannot be solved in the short term by changes to the application code. These weaknesses include poor representation of ponding operations within managed wetlands (WARMF and WestSim), simulation of irrigated agriculture using a single virtual crop[11] (WestSim) to represented crop type categories, and simulation of rainfall-runoff using a monthly timestep (WestSim).

To provide a common dataset for all models, including CalSim 3.0, WestSim input and output data will be maintained in a data storage system (DSS) format.[12] The resulting DSS file will be maintained and updated in, and released from, a single location for data integrity throughout the study.

The modeling tools are discussed in greater detail in the following sections.

Westside Simulation Model

WestSim was collaboratively developed by Reclamation and Lawrence Berkley National Laboratory. Initially developed using the Modflow finite difference platform, WestSim was one of the first applications of DWR's generic code IGSM2, subsequently renamed IWFM Version 2.4. WestSim's detailed finite element spatial resolution distinguishes it from other groundwater models covering the Westside Region; WestSim consists of 2,602 nodes, 2,176 elements, and 61 subregions, which include both water districts and managed wetlands (see Figure 4-1 and Figure 4-2). Detailed surface water and groundwater budgets may be output for each subregion. Other unique features of the model include its detailed depiction of surface water deliveries, agricultural and wetland water use, and subsurface tile drainage.

The current version of WestSim simulates historical conditions on the Westside from October 1969 through September 2000. WestSim model boundaries extend beyond the study area both to the north and south. The western boundary follows the California Coast Range based on the geologic extent of water-bearing soil materials. The eastern boundary follows the San Joaquin River and Fresno Slough. South of Fresno Slough, the eastern edge of the model domain follows water district boundaries.

[11] A virtual crop represents a group of crop classes (e.g., deciduous orchards) by assigning crop properties (e.g., crop coefficients) that are the (weighted) average of the individual crops.
[12] U.S. Army Corps of Engineers Hydrologic Engineering Center Data Storage System (DSS)

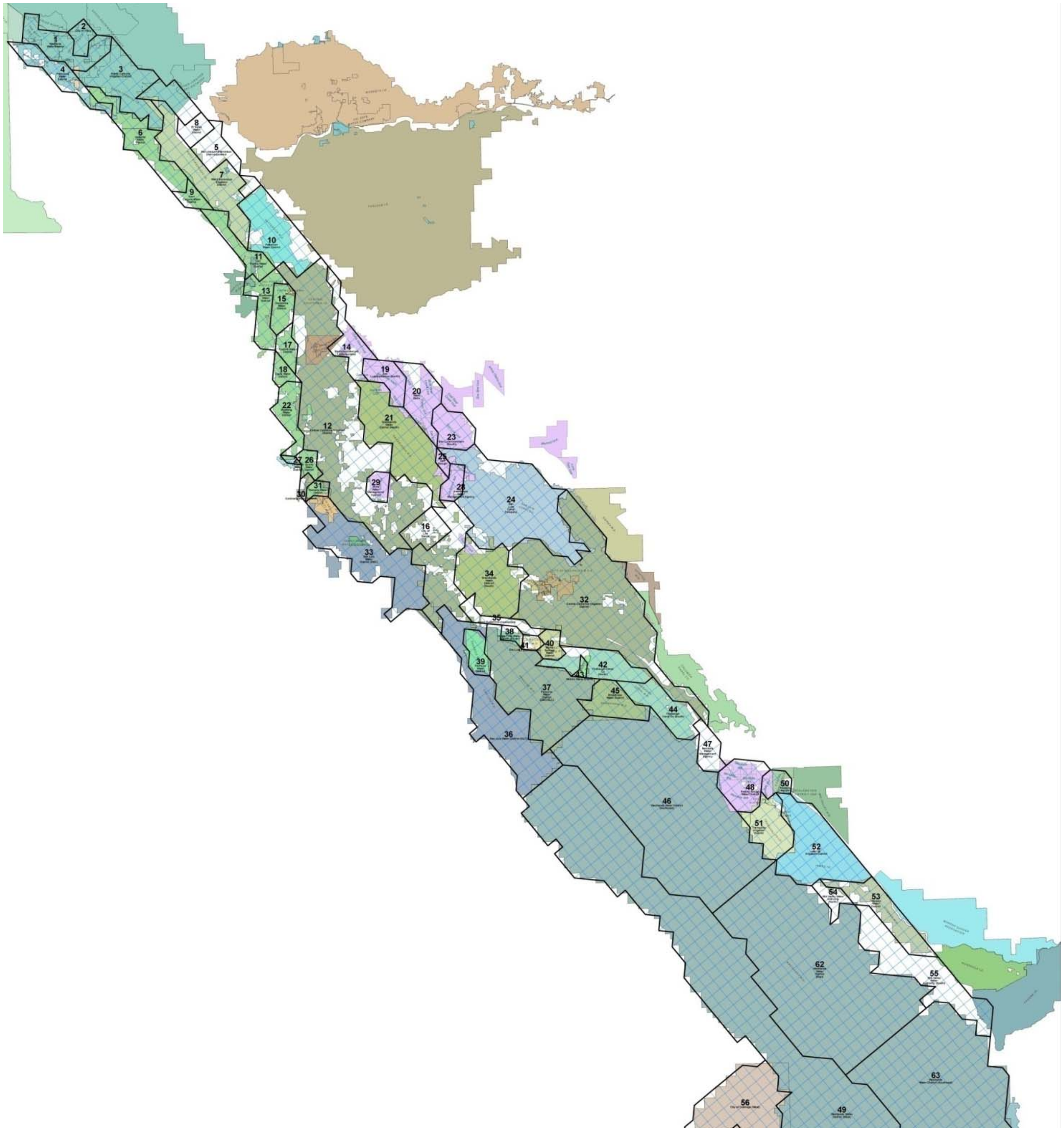


Figure 4-1. WestSim Subregions (North)

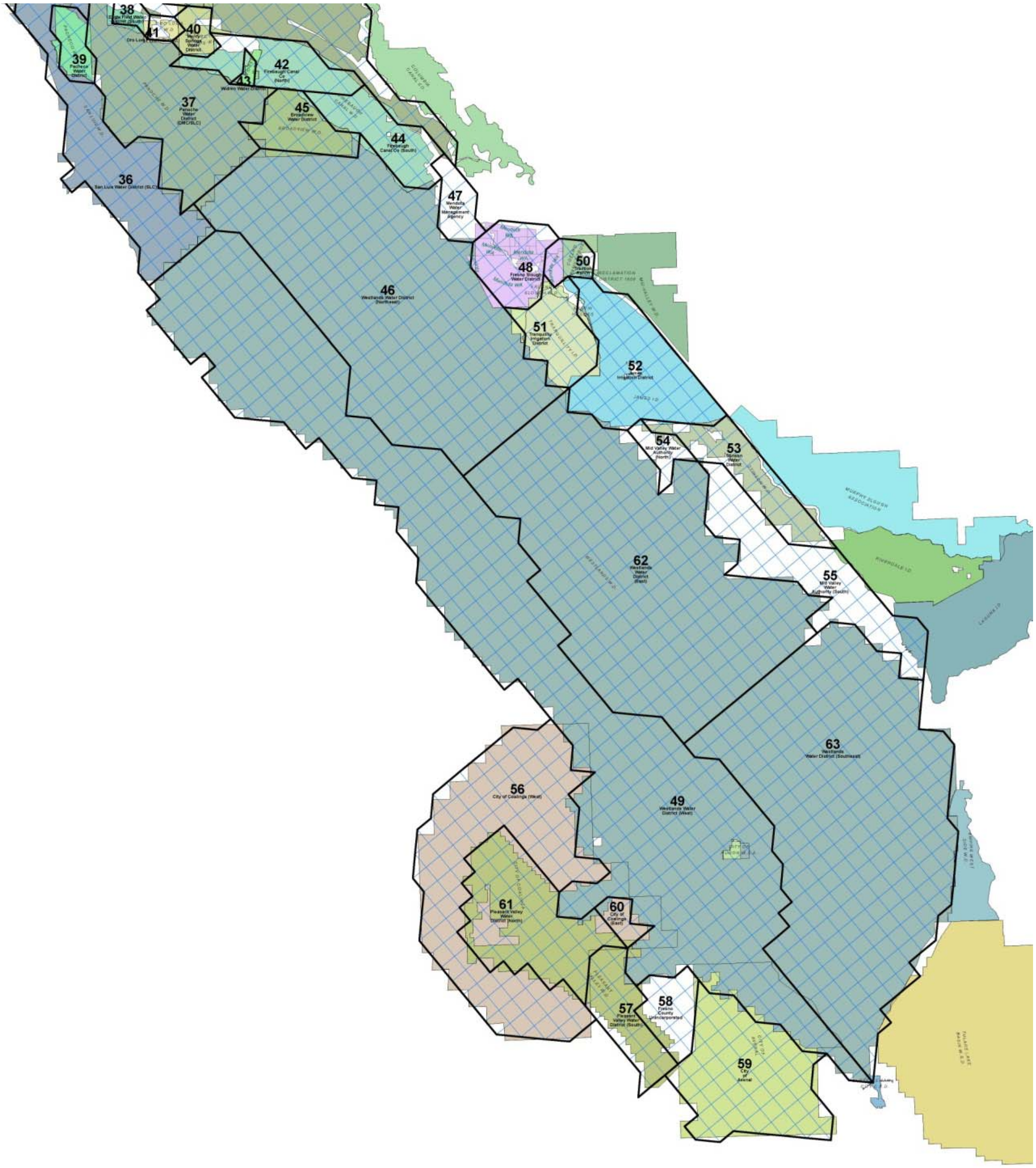


Figure 4-2. WestSim Subregions (South)

Boundary conditions used in the current WestSim model include both fixed and variable groundwater heads, and use of the IWFM small watershed routines to determine surface and subsurface inflows from lands outside of the finite element domain. The WestSim model eastern boundary uses time series data obtained by running the Central Valley Groundwater Surface Water (CVGSM) to obtain groundwater hydrographs at points located some distance east of the San Joaquin River and Fresno Slough. This variable head boundary condition permits WestSim to simulate flows and diversions along the San Joaquin River. Additional subsurface time series boundary conditions for each of WestSim's seven model layers are included in the model input files. It is expected that this study effort will use the latest update to IWFM (Version 3.01) and more recent statewide models (C2VSM, Central Valley application of IWFM) to establish and update relevant boundary conditions of the WestSim model.

Model refinement activities completed as part of Task 7 (Model Refinement) will be performed to complete the following:

- **Model Grid Expansion –** The WestSim model finite element grid will be expanded to include Oakflat Water District (an SWP Contractor) and Columbia Canal Company (a major diverter from the Mendota Pool and San Joaquin River)

- **Subregion Definitions –** With attention given to the study area, WestSim subregion delineations will be refined to reflect the current water catchment and political boundaries of managed wetlands, reuse areas, water districts, and city boundaries. Changes to model subregions and naming conventions will reflect current ownership, as of 2006/2007.

- **Model Element Definitions –** With the addition of groundwater model nodes and subregions, the model elements and geometry will be redefined using the current version of the WestSim and the data from geographic information system (GIS) after the above refinements.

- **Model Input Files –** Model input data will be reconfigured from the current version of WestSim to reflect the model refinements above. This will include changes to land use, surface water delivery, groundwater pumping, and water demand data.

Proposed Model Extension

A sequence of steps has been identified for refining WestSim for application to the Westside Salt Assessment, as follows:

1. Migration of WestSim input files from IWFM Version 2.4 to Version 3.01, including translation of time series input data to the DSS database format.

2. Extension of the model domain to include the Columbia Canal Company, located east of the San Joaquin River, to include Oak Flat Water District, which is an SWP contractor located adjacent to the California Aqueduct, and disaggregation of wetland regions to represent individual units of the Federal San Luis National Wildlife Refuge and units of the State North Grasslands Wildlife Management Area.

3. Extension of WestSim input data to include water years 2001 through 2007.

4. Calibration of WestSim for water years 2006 and 2007.

Simulated surface water and groundwater use and subsurface flows for each model subregion will be developed as inputs to application of SJR-WARMF.

Model Linkage

WestSim simulated output pertinent to SJR-WARMF includes the following:

- Deep percolation of irrigation water and precipitation from the root zone to the shallow (semiconfined) aquifer
- Groundwater pumping from the semiconfined and confined aquifers
- Subsurface agricultural drainage (from the Grasslands Drainage Area)
- Groundwater boundary fluxes along the western boundary (up-slope) of the unconfined aquifer
- Groundwater seepage to the stream system (primarily the San Joaquin River)

Watershed Analysis Risk Management Framework

WARMF is a publically available, deterministic watershed model that can used to simulate flow and water quality in any watershed. (The model and model documentation can be downloaded from the U.S. Environmental Protection Agency (EPA) Web site.[13]) Detailed descriptions of the model are available from several sources, including Chen et al. (2001), and Herr et al. (2000). The model has undergone peer review (Keller, 2001; Driscoll et al., 2004).

Flow Balance

WARMF divides a river basin into interconnected compartments of land catchments, river segments, and lakes.[14] Catchments are further subdivided into land surfaces (canopy) and soil layers, with a fluctuating groundwater table. The catchment model, driven by meteorological data, calculates soil infiltration, ET, groundwater exfiltration, surface runoff, and nonpoint source loading. River segments receive the inflows from catchments, upstream river segments, and point sources. Flow is routed using the kinematic wave approximation. Diverted flow is removed from rivers, and the portion used for irrigation is added to precipitation on irrigated land uses.

Within the catchment model, precipitation infiltrates into the ground, is held in detention storage, or contributes to overland flow. Flow through the soil profile is simulated by volumetric mass balance. With each timestep, the water table rises or falls based on the amount of water entering the soil and the amount leaving. Precipitation that percolates into the soil adds to its moisture content. If the moisture content is greater than field capacity, there is lateral flow to the stream network, which is calculated using Darcy's Law. Once the soil profile becomes saturated, precipitation contributes to overland flow (sheet flow), which is simulated and routed using Manning's equation. Potential ET is calculated from meteorological data using the Hargreaves equation. Actual ET is also a function of the moisture content in the root zone.

Irrigation efficiencies are not specified in WARMF. Rather, WARMF calculates the soil water budgets, accounting for surface water deliveries, groundwater pumping, precipitation, and ET. Runoff and drainage are calculated by volume balance; irrigation efficiencies can subsequently be extracted based on the amount of applied water and simulated ET.

"Near-surface" groundwater is defined as water down to the depth where it still interacts with surface water via lateral flow. Where bedrock does not occur at a shallow depth, as in the floor of the study area, the underlying unconfined

[13] www.epa.gov/athens/wwqtsc/html/warmf.html

[14] River basins are typically delineated into watersheds based on a digital elevation model (DWM). However, for the Westside Salt Assessment, water districts have significantly affected drainage patterns within the valley floor. Water district boundaries better define flow routing than the use of watersheds. In this TM, WARMF watershed objects refer to drainage areas, whether defined by natural topography or man-made drainage channels.

aquifer is referred to as "deeper groundwater." By default, WARMF assumes that the recharge to deeper groundwater is negligible compared to ET and lateral flow.

For the Westside Salt Assessment, time-varying recharge rates will be specified based on WestSim output. Pumping from deeper groundwater is represented as a point source, with an associated time series of flow and water quality.

Model Inputs

Inputs to WARMF for the water budget include model coefficients that do not vary with time, and time series data. Model inputs include the following:

- **Topography –** Watershed/catchment boundaries; catchment width, slope and aspect; stream elevations; and flow linkage between drainage areas and stream/channel segments, and between stream segments.

- **Soils –** Soil layer depth, field capacity, porosity, hydraulic conductivity, and rooting depth.

- **Land Use/Cover –** Land use imported into WARMF from an ArcView shapefile. The polygons in the shapefile are overlaid with WARMF catchment boundaries to calculate the percentage of each land use in each catchment. WARMF makes no distinction regarding where land uses occur within a catchment. Associated with each land use class are parameters that determine the amount of impervious surface and irrigation supplied.

- **Meteorology –** Precipitation, minimum and maximum temperatures, cloud cover, dewpoint temperature, air pressure, and wind speed. Each catchment uses the nearest meteorological station as the source of its data. Precipitation is adjusted with a multiplier, and temperature is shifted as necessary to account for spatial differences in meteorology between the station and catchment.

- **Surface Water Flow –** Daily flow time series data at the edge of the model domain when the WARMF model domain does not extend to the zero flow watershed boundaries. Additionally, measured flows within the model domain are used for calibration.

- **Groundwater Pumping –** Where surface water diversions do not suffice to meet irrigation demands, irrigation is supplemented either by groundwater or reuse of irrigation return flows (tailwater). Groundwater pumping can also be a model input instead of back-calculating from irrigation demand. Municipal use of groundwater only enters the WARMF model domain as a point source discharge of treated wastewater.

- **Irrigation Rates –** Annual irrigation rate in feet per year of different crops is used to allocate irrigation water.

Model Outputs

Model outputs include simulated daily surface water flows from catchments and stream segments.

Existing Model

The domain of the existing San Joaquin River model (SJR-WARMF) includes the majority of lands tributary to the San Joaquin River from Friant Dam to the Old River junction near Mossdale. Additionally, a link-node model has been developed to simulate tidal flows in the San Joaquin River reach between Mossdale and the Stockton Deep Water Ship Canal at Venice Island. The existing model does not simulate watersheds of the Stanislaus River above Tulloch Dam, the Tuolumne River above New Don Pedro Dam, or the Merced River above New Exchequer Dam. Inflow from these mountain watersheds is represented by the historical time series of reservoir releases. On the Westside of the San Joaquin Valley, the existing model excludes dynamic modeling of the Mud Slough/Salt Slough/Los Banos Creek watersheds, and the Orestimba Creek, Del Puerto Creek, Ingram Creek, and Hospital Creek watersheds. South of the Mendota Pool, the model excludes lands draining to Fresno Slough.

Proposed Model Extension

Under Task 2, SJR-WARMF will be refined to reflect the management units of the study area consistent with WestSim; simulation will be activated for the Westside watersheds that drain through the study area. The WARMF model of the San Joaquin River and its tributary land area between the gages and Lander Avenue and Vernalis has previously been calibrated for flow and water quality. Simulation results from this area will be combined in the model with simulated inflows from the updated Westside to predict flow and water quality at Vernalis.

Refinement of SJR-WARMF will begin following refinement of WestSim. As far as possible, inputs to SJR-WARMF will be consistent with WestSim, including definition of catchment boundaries. The WestSim model's calculation of land use is based on interpolation and extrapolation of known land use data. SJR-WARMF will be calibrated over a multiple-year simulation period using a fixed land use derived from DWR's most recent surveys of the study area.[15]

Integrated Water Flow Model Demand Calculator

The IWFM Demand Calculator was developed from surface water routing algorithms of the IWFM code (Version 3.01). Its development precedes the updated IWFM code (Version 4), and now offers a more sophisticated approach

[15] The main emphasis of DWR land use surveys is the mapping of agricultural land. Over 70 different crops or crop categories are included along with irrigation methods and water sources. The date of the survey varies generally by county, and is done approximately every 5 to 7 years.

to modeling soil moisture in the root zone. In December 2009, DWR released IWFM Demand Calculator. A future release of IWFM, namely Version 4.0, will be available in 2010 and will include the new IWFM Demand Calculator. However, IWFM Version 4.0 will not be readily applicable to the needs of the Westside Salt Assessment.

Version 4.0 of the IWFM Demand Calculator has several features that would benefit the Westside Salt Assessment, including simulation of different crop categories, simulation of permanent and semipermanent ponds, and a daily simulation option. Irrigation requirements will be calculated using the IWFM Demand Calculator for comparison with those calculated internally within WestSim. However, integration of Version 4.0 of the IWFM Demand Calculator with WestSim is beyond the scope of the current project.

Spreadsheet-Based Models

Spreadsheet-based water budgets will be completed for (1) the California Aqueduct, (2) the Delta-Mendota Canal, and (3) the San Joaquin River. Spreadsheet-based tools provide a more convenient environment for analysis, and display of results. Additionally, spreadsheet-based models will be developed for the managed wetlands. Direct simulation of permanent and seasonal ponds is not possible in WestSim and WARMF. Rather, surrogate routines must be used to mimic storage of water. In WestSim, the “lake” routine can be used as a surrogate.

Managed Wetland Simulation

The Wetland Management Simulation model (WetManSim) was developed for Reclamation at Lawrence Berkeley National Laboratory. WetManSim relies on descriptions of operations for wetlands, provided by water masters, refuge water supply coordinators, and refuge managers for Federal, State and private wetlands within the San Joaquin Valley (Quinn and Tulloch, 2002). The model considers the following wetland areas: Grassland Water District (combining the North and South grasslands wetland areas); San Luis, West Bear Creek, East Bear Creek, Freitas, and Kesterson units of the San Luis National Wildlife Refuge; Salt Slough and China Island units of the North Grasslands Wildlife Management Area; Los Banos Wildlife Area; and Volta Wildlife Management Area.

WetManSim tracks the fate of monthly applied water within the San Joaquin Valley wetlands by considering a variable flooded area of variable ponded depth. The model considers three distinct periods of different water operations, as follows:

- **August to October: Flood-Up Period –** Flooded area and flooded depth gradually increase.

- **November to February: Maintenance Period –** Flooded area is assumed constant; applied water is used to maintain a constant ponded depth of 12 inches.

- **March to July: Drawdown Period –** Seasonal marshes are drawn down, irrigation occurs to encourage seed propagation.

DWR, as part of California Water Plan updates 2005 and 2009, has developed water budgets for wetlands in the San Joaquin Valley. These water budgets consist of a set of individual spreadsheet models for each managed wetland and for each of 8 water years from 1998 to 2005. Their purpose is to estimate the monthly volume of return flow from irrigation. In contrast to WetManSim, DWR explicitly considers a range of land use or land cover within each wetland, including permanent ponds, semipermanent ponds, seasonal ponds with different flood-up and drawdown cycles to encourage different aquatic plants (swamp Timothy, watergrass), irrigated cropland, and riparian and native grasslands.

For the Westside Salt Assessment, a set of spreadsheets will be developed, combining features of DWR water budgets and WetManSim. DWR's spreadsheets will be further refined to estimate deep percolation from precipitation and irrigation, and stormwater runoff. Principal difficulties are obtaining a reasonable characterization of habitat acreage and associated water practices for each managed wetland unit, and obtaining records of measured drainage return flows for model calibration. Continuous flow data are available for the lower reaches of Mud Slough and Salt Slough. However, this measured flow is a mix of return flows from managed wetlands and adjacent water districts (Central California Irrigation District and San Luis Canal Company).

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Chapter 5
Data and Data Sources

This chapter briefly summarizes data requirements and data sources that will be used for the water budget analyses. Discussion of data and data sources in this chapter is limited to data needed for model update and refinement. This chapter does not discuss data already obtained or developed for WestSim and SJR-WARMF (e.g., soils data, agronomic data, groundwater aquifer properties).

Meteorological Data

The following sections described meteorological data that will be used to update and refinement of models for water budget analyses.

Precipitation

Daily precipitation records for 32 National Climatic Data Center (NCDC) weather stations in California's Central Valley have been assembled by DWR for October 1921 through December 2007 as part of C2VSim. This work is described by Brush (2009). Table 5-1 summarizes sources of daily data.

Table 5-1. Precipitation Gage Data Sources for Westside Region

Location	Station ID	Station Name	Lat.	Long.	Elevation (feet)	Source	Start	End
Tracy Carbona	NCDC 9001	Tracy Pumping Plant	37 48'	120 35'	61	NCDC	10/1/1969	12/31/2005
	NCDC 8999	Tracy-Carbona	37 42'	121 25'	140	UCD	1/1/2006	9/30/2007
Los Banos	NCDC 5118	Los Banos	37 03'	120 52'	120	EarthInfo	10/1/1969	12/31/2004
	NCDC 5118	Los Banos	37 03'	120 52'	120	UCD	1/1/2006	9/30/2007
Kettleman	NCDC 4536	Kettleman Station	36 04'	120 05'	508	DRI	10/1/1969	12/31/2005
	CIMIS 21	Kettleman CIMIS	35 52'	119 54'	340	UCD	1/1/2006	9/30/2007

Key:
CIMIS=California Irrigation Management Information System
DRI=Desert Research Institute
NCDC=National Climatic Data Center
UCD=University of California at Davis

Evapotranspiration

Monthly values of reference evapotranspiration (ETo) are available from California Irrigation Management Information System (CIMIS). Table 5-2 summarizes stations within or adjacent to the Study Area. DWR has also developed ETo spatial data on a 2-kilometer grid. These data will be reviewed to determine the significance of the ET spatial variation across the study area.

Table 5-2. Available CIMIS Meteorological Stations

Station Name	Station ID	Lat.	Long.	Elevation (feet)	Start	End
Five Points	2	36 20’ 11”	120 06' 47”	285	06/1982	To date
Firebaugh/Telles	7	36 50’ 04”	120 35' 25”	185	09/1982	To date
Stratford	15	36 09’ 27”	119 51' 00”	193	10/1982	To date
Kettleman	21	35 52’ 08”	119 53' 39”	340	11/1982	To date
Los Banos	56	37 05’ 36”	120 45' 39”	95	06/1982	To date
Modesto	71	37 38’ 43”	121 11' 16”	35	06/1982	To date
Kesterson	92	37 13’ 55”	120 52' 51”	75	11/1982	To date
Westlands	105	36 38’ 00”	120 22' 55”	191	04/1982	To date
Panoche	124	36 53’ 25”	120 43' 55”	183	07/1982	To date
Patterson	161	37 26’ 24”	121 08' 20”	183	08/1982	To date
Tracy	167	37 43’ 34”	121 28' 26”	82	09/1982	To date

Source: CIMIS, 2010`

Key:
CIMIS = California Irrigation Management Information System

Land Use

Land use data are central to development of the water budgets. These data are needed to estimate stormwater runoff, ET, and irrigation demands. Data on land use are available from several sources discussed below.

DWR County Land Use Surveys

DWR surveys of land use began in the early 1950s for specific projects and investigations. By the mid-1960s, DWR had started an ongoing program to perform land use surveys every year. Since 1950, DWR has conducted over 250 land use surveys of all or parts of California's 58 counties.

The main emphasis of DWR's land use surveys is mapping agricultural land. Over 70 different crops or crop categories are included in the surveys.[1] Urban and native vegetation (undeveloped) areas are mapped, but not with the detail used for agricultural land. Land use surveys are conducted by county, and are updated approximately every 7 years.[2] County surveys available for the Westside of the San Joaquin Valley are listed in Table 5-3.

[1] Land use classifications for these surveys are described in the Standard Land Use Legend (DWR, 1993).
[2] These data is available from DWR’s Division of Planning and Local Assistance at:
http://www.landwateruse.water.ca.gov/basicdata/landuse/digitalsurveys.cfm

Table 5-3. County Land Use Surveys

Counties Intersecting Study Area[1]	Years Land Use Surveys Performed
San Joaquin	1988,1996
Stanislaus	1996, 2000
Merced	1995, 2002
Fresno	1986, 1994, 2000
Kings	1991, 1996, 2003

Note:
[1] The model domain covers parts of San Joaquin, Stanislaus, Merced, Fresno, and Kings counties.

DWR Water Plan Data

DWR's land and water use database comprises annual data related to agricultural, managed wetlands, and urban lands for the *California Water Plan Update* (2009).[3] Available data include annual agricultural land use for 20 crop categories for water years 1998 through 2005. These land use data are derived from the county land use surveys described above, and interpolation/extrapolation based on agricultural commissioners' reports. The data are not georeferenced, but are organized by Detailed Analysis Unit (DAU) and by county. The valley floor part of the study area comprises part of DAU 186 (the portion that lies within the Delta), DAU 216, and part of DAU 244.

As part of the *Water Plan Update*, DWR staff have completed annual water balances for the Central Valley for water years 1998 through 2005 (2009). These land-use-based water balances include information on area and types of habitat for managed wetlands in the San Joaquin Valley.

USGS Land Use Data

Derived from early to mid-1990s Landsat Thematic Mapper satellite data, National Land Cover Data (NLCD) are a 21-class land cover classification scheme applied consistently over the United States. Spatial resolution of the data is 30 meters, and that data are mapped in the Albers Conic Equal Area projection, North American Datum (NAD) 83. The NLCD are provided on a state-by-state basis. For the Westside Salt Assessment, the NLCD contains more land classes for nondeveloped lands in the upstream watersheds.

Water Agency Data

Water districts receiving water from the CVP report annual crop acreage to Reclamation. These data are based on projected acreage before planting. Actual crop acreage depends on CVP water allocations for south-of-Delta contractors. The following extract from the *Westside Integrated Water Resources Plan* (SLDMWA, 2006) illustrates the difficulty in obtaining accurate estimates of crop acreage.

[3] These data are available from the Division of Planning and Local Assistance at http://www.landwateruse.water.ca.gov/annualdata/datalevels.cfm

> *Irrigated acreage data for 1999 was obtained from district records. The data is actually harvested acreage, including acres harvested more than once (multiple-cropped acres) in 1999. For example, if an acre of lettuce is harvested in the spring and the same acre is replanted to grains and harvested in the fall, two irrigated acres are counted. Therefore, the amount of harvested acres typically exceeds the amount of land irrigated to produce those harvests. The 1999 harvested acreage data did not include acreage that was not harvested because of a water shortage in 1999. The shortage, reflective of a CVP allocation 30 percent below full contract entitlement, is representative of the chronic shortages experienced by the region.*
>
> *The Westside districts estimated 49,709 acres were fallowed in 1999 as a result. This acreage was added into the total 1999 acreage to obtain an estimate of potential irrigated acreage if water supply had not been a limiting factor.*
>
> *Irrigated pasture is not actually harvested but is included as irrigated acreage in the analysis. However, the 1999 harvested acreage data did not include other irrigated acreage that was not harvested. This acreage is primarily immature, non-bearing fruit trees and vines that did not produce a crop in that year. Westside water users estimated an additional 30,000 acres for this irrigated land in 1999. The acreage data also allowed for 14,000 acres of land retired under the Westlands WD land acquisition program. The acreage was not included in the 1999 total.*

Wildlife refuges that have entered into water supply contracts with Reclamation as a result of the CVPIA are required to prepare Refuge Management Plans. These Refuge Management Plans are updated every 5 years, and were first prepared in 2005; updates are due in 2010. The refuges also submit annual updates to Reclamation describing actions taken in implementing the Refuge Management Plan for the previous year, and forecast implementation actions and proposed changes for the current year. The annual update is limited to reporting on best management practices (BMP). The 2005 Refuge Management Plans (revised 2006) report habitat acreage for 2004.

Land Use Categories

Categories of land use and land cover vary between data sources, as follows:

- DWR county land use data contain about 167 separate land cover designations
- NLCD contain about 15 separate land cover designations

- CV-SALTS selected 33 land cover classes

Correspondence between DWR, NLCD, and CV-SALTS land cover classes, and the proposed land cover classes for this study are shown in Table 5-4.

Proposed Methodology

- Spatial analysis
  - Develop GIS land use layer from mosaic of DWR county land use surveys.
  - Where DWR land use is not available (generally in rangeland and wildlands), supplement with 2001 NLCD data.
  - Condense land use classes.
  - Intersect land use with water-user (e.g., water districts, refuges) polygons to obtain land use for each water-user.
- Tabular analysis
  - For land use within managed wetlands, replace DWR spatial data with land use from 2005 refuge Water Management Plans, WetManSim, and/or DWR annual water balances.
  - Scale the area of irrigated agriculture to develop annual time series for water years 2000 to 2007 that match annual estimates of irrigated land use obtained from district reports submitted to Reclamation and DWR water balances conducted for the *California Water Plan*. Adjust acreage of fallow land to preserve constant total acreage.

Table 5-4. Land Use Classes

CV-SALTS	California Water Plan	WestSim	DWR Land Use ID	Westside Salt Assessment
Perennial forages	Alfalfa	Alfalfa	P1	Alfalfa
Orchard	Almonds/pistachios	Orchard	D12,D14	Almonds/pistachios
Cotton	Cotton	Cotton	F1	Cotton
Warm season cereals and forages	Corn	Field crops	F6	Corn
Other row crops	Cucurbits	Truck crops	T9	Cucurbits
Other row crops	Beans (dry)	Field crops	F10	Beans
Warm season cereals and forages	Other field	Field crops	F,F4,F7,F8	Other Field
Other row crops	Other field	Field crops	F3,F9,F11,F12	Other Field
Winter grains and safflower	Grain	Grain	G, G1,G2,G3,G6	Grain
Other row crops	Onions and garlic	Truck crops	T10	Onions and Garlic
Orchard	Other deciduous	Orchard	D,D1-D10,D13	Other Deciduous
Perennial forages	Pasture	Pasture	P, P2-P7	Pasture
Other row crops	Potatoes	Truck crops	T12	Potatoes
Rice	Rice	Rice	R	Rice
Other row crops	Sugar beets	Sugar beets	F5	Sugar beets
Winter grains and safflower	Safflower	Field crops	F2	Safflower
Olives, citrus, and subtropicals	Subtropical	Citrus and olives	C,C1,C8,C9,C10	Subtropical
Other row crops	--	Citrus and olives	C9	--
Other row crops	Tomatoes, hand-picked	Tomatoes, hand-picked	T15	Tomatoes, hand-picked
Other row crops	Tomatoes, machine-picked	Tomatoes, machine-picked	T15	Tomatoes, machine-picked
Other row crops	Other truck	Truck crops	T, T1,T11,T13,T14 T17,18,T19,T20-T25	Other truck
Flowers and nursery	Other truck	Truck crops	T16	Other truck
Vines	Vineyards	Vineyards	V,V1,V2,V3,F4,C8,T19	Vineyards
Marsh	N/A	Seasonal wetland	NR4	Seasonal wetland – irrigated
Marsh	--	Permanent wetland	NR5	Permanent wetland – Irrigated
Marsh	--	Permanent wetland	NR1,NR2,P5	Permanent wetland – nonirrigated
Paved areas	--	Urban	UV4,UV6	Paved areas
Urban residential	--	Urban	U,UR,UR3,UR4,UR21-UR24,UR31-UR34,UR41-UR44	Urban residential
Urban landscape	--	Urban	UL,UC8,UI12,UL1-UL4,Z	Urban landscape
Urban commercial and industrial	--	Urban	UC,UC1-UC7,UI,UI1-UI3,UI7-UI11	Urban commercial and industrial

Table 5-4. Land Use Classes (Contd.)

CV-SALTS	California Water Plan	WestSim	DWR Land Use ID	Westside Salt Assessment
Urban C&I, low impervious surface	--	Urban	UI6,UI14,UI15,UV, UV1,UV3	Urban C&I, low impervious surface
Farmsteads	--	Urban	S1,S3,UR1,UR2,UR11-UR14	Farmsteads
Farmsteads	--	Urban	S1,S3	Farmsteads
Other CAFOs	--	Urban	S2,S4	Other CAFOs
Sewage treatment plant, including ponds	--	Urban	UI13	Sewage treatment plant, including ponds
Native classes unsegregated	--	Native Vegetation	E,NC,NS	Native classes unsegregated
Deciduous forest	--	Riparian	NR,NR3,C10	Deciduous forest
Fallow	--	Native Vegetation	I1,I2	Fallow
Shrub/scrub	--	Native Vegetation	NB1,NV2-NV4	Shrub/scrub
Barren land	--	Native Vegetation	NB,NB2-NB5	Barren land
Mixed forest	--	Native Vegetation	NV5,NV6	Mixed forest
Evergreen forest	--	Native Vegetation	Not used (NLCD class)	Evergreen forest
Grassland/herbaceous	--	Native Vegetation	NV,NV1,NV7	Grassland/herbaceous
Water	--	Native Vegetation	NW	Water

Key:
-- = Not applicable
CAFO = Concentrated Animal Feed Operations
C&I = Commercial and Industrial
CV-SALTS – Central Valley Salinity Alternatives for Long-Term Sustainability
DWR = California Department of Water Resources
N/A = not applicable
NLCD = National Land Cover Data
WestSim = Westside Simulation Model

Pesticide Permit Data

Recent information on land cover types may be developed based on pesticide application permits obtained from the California Department of Pesticide Regulation (DPR) to update land cover information for the Westside Region. Electronic land cover data from pesticide application permits obtained should be available for counties within the Westside Region. Some counties do not have electronic data available that are georeferenced for GIS; some work will be required to develop these data. One effort could include manually combining the Assessor's Parcel Number data layer from the County Assessor's office with the DPR data layer to develop appropriate GIS coverage for the study area. The added value of such an effort is not certain at this time and is currently being evaluated.

Central Valley Project Delivery Data

The Central Valley Operations Office of Reclamation reports monthly surface water deliveries to CVP contractors. Reclamation's Report of Operations Monthly Delivery Tables (Tables 24, 25, and 26) provide data on deliveries from the Delta-Mendota Canal, Mendota Pool, and Joint Reach of the California Aqueduct (2010).

San Joaquin River Diversions

In general, surface water diversions from the San Joaquin River are poorly documented. The most comprehensive study was conducted in 1985 – 1986 by the Central Valley RWQCB (1989). This study describes 89 points of water diversion along the 150-mile river reach from Mendota Dam near the town of Mendota to Mossdale Bridge near Tracy.

WestSim input files contains monthly surface water diversions/deliveries for 83 stream nodes. Stream nodes 1 through 24 represent stream nodes along the San Joaquin River within the model domain, while stream nodes 25 through 83 represent locations to which surface water deliveries are made from outside the model area (e.g., Joint Reach of the California Aqueduct, Delta-Mendota Canal[4]). Surface water diversion data (record numbers 1 to 24) are historical data outputs taken from SJRIO, developed by SWRCB.

Streamflow Data

Daily streamflow data are available from a variety of sources, including, but not limited to, USGS, DWR (the water data library and California Data Exchange Center (CDEC)), San Luis Water District, and interested stakeholders and Delta-Mendota Water Authority partnerships. Flow gages on the San Joaquin River and its tributaries are summarized in Table 2-1.

Surface Agricultural Drainage

Surface agricultural drainage results from canal operational spills and tailwater (usually associated with flood or furrow irrigation). These flows are conveyed to the San Joaquin River through natural channels (e.g., Orestimba Creek) or artificial drains (e.g., Grayson Road Drain). Gaged flows on Salt Slough and Mud Slough measure a mix of agricultural drainage and drainage from managed wetlands. With the exception of Orestimba Creek, there is little gage data for the Westside tributaries and drains.

[4] Although the Delta-Mendota Canal lies partially within the model domain, it is not represented explicitly in WestSim.

The Central Valley RWQCB 1989 study lists 193 discharge points along the San Joaquin River between Mendota Dam and the Mossdale Bridge; approximately half of these are located between the Hills Ferry Road Bridge near Newman and Vernalis.

Gaged flows for Orestimba Creek provide the best data for calibrating agricultural return flows. Data for a limited time period are also available for Hospital Creek and Ingram Creek. Kratzer et al. (1987) identified 10 water districts that discharged agricultural drainage to the San Joaquin downstream from the Merced River confluence, as follows:

- Central California Irrigation District
- Del Puerto Water District
- Foothill Water District
- Hospital Water District
- Kern Canon Water District
- Orestimba Water District
- Patterson Water District
- Salado Water District
- Sunflower Water District
- West Stanislaus Irrigation District

Patterson Irrigation District has built a flow detention reservoir and a tailwater recovery system to reduce discharge to the San Joaquin River from both West Stanislaus and Patterson irrigation districts. Kratzer et al. (1987) assumed that 30 percent of irrigation deliveries returned to the San Joaquin River. However, agricultural return flows from CVP water service contractors are likely to have significantly reduced return flows because of reduced CVP south-of-Delta allocations in recent years. Kratzer et al. (1987) identified agricultural drainage discharges from the Westside and mapped water districts to drainage channels.

Groundwater Elevations

Groundwater elevation data are available through the State DWR Groundwater Information Center Web site (http://www.water.ca.gov/groundwater/) and from independent measurements by private well owners, water districts, and municipal water purveyors. A database management system exists for the Westside study area, developed as part of the existing WestSim model. Updated groundwater elevation data for the 7-year period from 2000 through 2007 will be downloaded from each of the available sources and stored in the existing data management system. These data will be used for calibrating the groundwater model, and for illustrating regional trends in past and current groundwater elevations.

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Chapter 6 Approach for Westside Region Water Budget Completion

The purpose of Task 2 – Westside Region Water Budget is to develop a water budget(s) for the Westside Region. The water budget(s) will be used to identify salt and nitrate sources, transport, and fate within the study area. To achieve an accurate water budget accounting using the best available information and models, a careful approach is needed to reduce the number of modeling iterations and to increase the level of communication between project team members. The purpose of Chapter 6 is to provide a work flow diagram that includes time and level of effort necessary based on the available budget and schedule to fulfill Task 2 requirements. Table 6-1 lists the models discussed in earlier chapters while also providing the agency or consulting firm responsible for completing the work.

Table 6-1. Work and Data Sharing Flowchart

Validated Models	Full Title	Modeler
WetManSim	Managed Wetland Simulation	LBNL/MWH
WARMF	Watershed Analysis Risk Management Framework	Systech
IWFM Demand Calculator	Integrated Water Flow Model Demand Calculator	MWH
WestSim	Westside Simulation Model Application of Integrated Water Flow Model	MWH
Spreadsheet Water Budget and Calibration Tools	California Aqueduct	Reclamation
	Delta-Mendota Canal	Reclamation
	San Joaquin River	Reclamation
PestCrop	Combined Pesticide Permit Data and Assessor's Parcel Data using GIS	MLJ

Key:
GIS = geographic information system
IWFM = Integrated Water Flow Model
MLJ = Michael Johnson, LLC
MWH = MWH Americas, Inc.
PestCrop = Pesticide Permit Model
Reclamation = U.S. Department of Interior, Bureau of Reclamation
Systech = Systech Water Resources, Inc.
WestSim = Westside Simulation Model
WetManSim = Wetland Management Simulation Model

Model Flow Diagram

Each model listed in Table 6-1 requires, as input, a unique dataset derived either from measured data, engineering and scientific assumptions, or output of validated models. This assessment relies heavily in all three of these categories, with the greatest emphasis on the use of validated models to ultimately arrive at a water budget for the region at a resolution commensurate with the need to assess salt and nitrate sources and their fate and transport.

With each model, a number of input and output files are common or, at a minimum, shared for purposes of comparison and calibration. It is important to note the files that will need to be shared as the assessment progresses. Table 6-2 lists only relevant files that can be classified as shared, with the emphasis on using the best data available for each model.

Table 6-3 conveys the interdependency of the models being used in this assessment. The data files identified in this table are limited to only those that shared among models and described in Table 6-2. The prefix identifies the origin of the file data (i.e., model name) and whether the data are time series data (i.e., prefix followed by TS_). The flow of modeling is predominantly from left to right, with model runs shaded in grey. Shared output files follow the model run and are shown as input files in subsequent models. In some cases, iterations among two or more models take place to converge on a solution that provides consistency between models. Spreadsheet models to the right are used to post-process numerical model data, and then to share resulting output as part of the calibration effort that will take place for the 2-year period of 2006/2007. The GIS effort in defining crop types occurring in 2006/2007 will commence towards the end of the modeling effort, and will be used in the calibration process and to understand the sensitivity of the models to changing crop patterns.

The level of effort and schedule are reflected in the table in the weeks going down the page. In some cases, model development can work in parallel and begin to share data, when available. This is the case with IWFM Demand Calculator, WestSim, and WARMF. All three models should be developed concurrently, noting that the identified data from each will be needed at a given milestone. Other models such as WetManSim may need to be completed at the beginning of the assessment period or, in the case of the river/canal spreadsheets, at the end because of their unique purpose for the overall model assessment effort.

The WARMF model will be relied on heavily for water budget and streamflow data when it is necessary to know the volume and makeup of water from each source (i.e., CVP from the Delta-Mendota Canal, CVP from the Mendota Pool, and groundwater), including subsurface groundwater inflows to rivers and streams. The overall schedule is estimated to be 9 to 10 weeks before calibration of the models can be completed. Task 2 deliverable presenting the water budget(s) for the study area will follow 2 weeks after initial calibration.

Table 6-2. Shared File Descriptions and Purpose

Model	Shared File Name	Shared File Description	Purpose
WetManSim (WMS)	WMS_Wetland Operations	Input-Wetland operations for wet/dry hydrologic year-types	Understand and reflect managed wildlife refuge/preserve (wetland) water use operations
	WMS_TS_Surface Water Diversion	Input-Available surface water by contract for diversion to wetlands	General accounting of available surface water supplies
	WMS_TS_Wetland Inflow	Output-Calculated surface water diversions to wetlands	Used as input to the WestSim lake routine to approximate wetland water use
	WMS_TS_Wetland Outflow	Output-Calculated wetland discharge flows to downstream surface waters	Used as input to the WestSim lake routine to approximate wetland water use
WARMF	WRMF_Field Capacity	Input-Field capacity and other crop irrigation parameters	Agicultural irrigation dependency parameters for use in irrigation modules in IDC and WestSim
	WRMF_TS_Precipiation	Input-Rainfall over study area	Shared precipitation file
	WRMF_TS_ET	Output-Calculated evapotranspiration over study area	Shared ET file for consistency between WestSim and WARMF
	WRMF_TS_Surface Water Flows by Stream/River Reach	Output-Calculated surface water flows by stream/river reach	Shared surface water flow data for comparison with WestSim and measured stream/river flows
	WRMF_TS_Water Budget by Catchment/Subregion	Output-Water Budget for each catchment area	Water budget data used for model calibration across model platforms and final deliverable from Task 2
IWFM Demand Calculator (IDC)	IDC_TS_CropAgDemands	Output-Calculated agricultural demands	Calculated crop water demands based on common set of parameters
WestSim (WstSm)	WstSm_Eastside Boundary Conditions	Input-Groundwater and surface water boundary conditions along the eastside	Eastside surface water inflow data from river/stream flows and agricultural return flows
	WstSm_Elements/ Subregions	Input-Geometry of model to define catchment areas	Shared geometry data of catchment/subregion areas for consistency between WestSim and WARMF
	WstSm_Small Watershed Definitions	Input-Area and water use for small watersheds along the westside	Shared small watershed data for consistency between WestSim and WARMF
	WstSm_Stream/ River Nodes	Input-Stream node locations identifying stream location and reach definitions	Shared to identify resolution of stream/river definitions and reach descriptions
	WstSm_Lake Routine	Input-Lake operations data for use in simulating wetlands	Shared lake operations data with WARMF
	WstSm_TS_CropType by Subregion	Input-Crop acreage data over model simulation (up to predefined number of crop types)	Calculated crop acreage based on interpolated/extrapolated best available crop inventory data
	WstSm_TS_Landuse by Element	Input-Four (4) classification land use data (ag, urban, native, and riparian) by element	Spatial land use data for consistency with WARMF

Table 6-2. Shared File Descriptions and Purpose (Contd.)

Model	Shared File Name	Shared File Description	Purpose
WestSim continued	WstSm_TS_Groundwater Budget by Subregion	Output-Groundwater budget for subregions	Groundwater budget for use by WARMF in water budget
	WstSm_TS_Groundwater Hydrographs	Output-Groundwater hydrograph data	Groundwater hydrographs for use in calibration with measured data
	WstSm_TS_Lake Budget by Lake	Output-Lake budget to evaluate wetland operations and water use	Used for calibration with WetManSim wetland operations
	WstSm_TS_Streamflow Hydrographs	Ouput-Streamflow hydrographs	Stream/river monthly hydrographs for calibration
	WstSm_TS_Surface Water Budgets by River Reach	Output-Surface water budget by stream/river reach	Stream/river budgets for consistency with WARMF
	WstSm_TS_Water Use Budget by Subregion	Output-Water use budget information by subregion	Water use budget for use in comparing with WARMF
California Aqueduct (CA)	CA_TS_Delivery Data	Input-Actual and modeled surface water delivery data	Compilation of WARMF and WestSim model data
	CA_TS_Gage Data	Input-Measured canal flow data	Measured canal flow data
	CA_TS_Canal Flow	Output-Modeled canal flows along predefined reaches	Used for calibration and presentation of canal operations
Delta-Mendota Canal (DMC)	DMC_TS_Delivery Data	Input-Actual and modeled surface water delivery data	Compilation of WARMF and WestSim model data
	DMC_TS_Canal Flow	input-Measured canal flow data	Measured canal flow data
	DMC_TS_Gage Data	Output-Modeled canal flows along predefined reaches	Used for calibration and presentation of canal operations
San Joaquin River (SJR)	SJR_TS_Delivery Data	Input-Actual and modeled surface water delivery data	Compilation of WARMF and WestSim model data
	SJR_TS_Gage Data	input-Measured river flow data	Measured river flow data
	SJR_TS_Canal Flow	Output-Modeled river flows along predefined reaches	Used for calibration and presentation of river operations
Pesticide Permit Model (PestCrop)	PestCrop_Assessor's Data	Input-GIS shapefile of Assessor's land use information	Land ownership and use data for calibration of models
	PestCrop_Pesticide Permit Data	Input-Pesticide Permit Data from California Department of Pesticide Regulation	Crop types based on pesticide permit data
	PestCrop_LandUse 06/07	Output-Crop information for 2006/2007 calibration period	Crop data for calibration and sensitivity of WestSim and WARMF model results

Key:
ET = evapotranspiration
GIS = geographic information system
IWFM = Integrated Water Flow Model
WARMF = Watershed Analysis Risk Management Framework

Table 6-3. Model Workflow and Data Sharing

Time	Numerical Models								Spreadsheet Models Used for Model Calibration						GIS	
	WetManSim (WMS)		IWFM Demand Calculator(IWFMDC)		WestSim (WstSm)		WARMF		California Aqueduct (CA)		Delta-Mendota Canal (DMC)		San Joaquin River (SJR)		Pesticide Permit Model (PestCrop)	
Weeks	Input Files	Output Files	Input Files	Output Files	Input Files	Output Files	Input Files	Output Files	Input Files	Output Files	Input Files	Output Files	Input Files	Output Files	Input Files	Output Files
1	WMS_TS_Surface Water Diversion		WstSm_TS_CropType by Subregion		WstSm_Elements/ Subregions		WstSm_Elements/ Subregions									
			WRMF_TS_ET		WstSm_Stream/River Nodes		WstSm_Stream/River Nodes									
			WRMF_Field Capacity		WstSm_Small Watershed Definitions		WstSm_Small Watershed Definitions									
2			Model Run		WstSm_Eastside Boundary Conditions		WstSm_TS_CropType by Subregion									
	WMS_Wetland Operations			IWFMDC_TS_CropDemand	WstSm_TS_CropType by Subregion		WstSm_Eastside Boundary Conditions									
	Model Run				WRMF_Field Capacity		WRMF_Field Capacity									
3		WMS_TS_Wetland Inflow			WMS_TS_Wetland Inflow		WstSm_Lake Routine									
		WMS_TS_Wetland Outflow			WMS_TS_Wetland Outflow											
					WstSm_Lake Routine											
4					Model Run											
					IWFMDC_TS_CropDemand	WstSm_TS_Lake Budget by Lake	WstSm_TS_Lake Budget by Lake									
						WstSm_TS_Groundwater Budget by	WstSm_TS_Groundwater Budget by Subregion									
5							Model Run									
			WARMF_TS_ET		WARMF_TS_ET		WARMF_Precipitation	WARMF_TS_ET								
			WARMF_Precipitation		WARMF_Precipitation			WARMF_TS_Surface Water Flows by Stream/River Reach								
6								WARMF_Water Budget by Catchment/Subregion								
			Model Run		Model Run											
						WstSm_TS_Surface Water Budgets by River Reach	WstSm_TS_Groundwater Budget by Subregion									
7						WstSm_TS_Water Use Budget by	WstSm_TS_Water Use Budget by Subregion		CA_TS_Gage Data	CA_TS_Canal Flow	DMC_TS_Gage Data	DMC_TS_Canal Flow	SJR_TS_Gage Data	SJR_TS_Canal Flow		
				IWFMDC_TS_CropDemand	IWFMDC_TS_CropDemand		Model Run		CA_TS_Delivery Data		DMC_TS_Delivery Data		SJR_TS_Delivery Data			
					WstSm_TS_Landuse by Element			WARMF_TS_Surface Water Flows by Stream/River Reach								
8					Model Run			WARMF_Water Budget by Catchment/Subregion	Model Run		Model Run		Model Run			
						WstSm_TS_Groundwater Hydrographs										
						WstSm_TS_Streamflow Hydrographs									PestCrop_Pesticide Permit Data	
9					PestCrop_LandUse 06/07										PestCrop_Assessor Data	PestCrop_LandUse 06/07
					Calibration		Calibration		Calibration		Calibration		Calibration			
					CA_TS_Canal Flow		CA_TS_Canal Flow									
10					DMC_TS_Canal Flow		DMC_TS_Canal Flow									
					SJR_TS_Canal Flow		SJR_TS_Canal Flow									
					Calibration		Calibration		Calibration		Calibration		Calibration			

Notes: First prefix followed by "_" is model platform name
Model platform name followed by TS_ is timeseries data

Abbreviations:
GIS - Geographic Information System
IWFM - Integrated Water Flow Model
WARMF- Watershed Analysis Risk Management Framework
WestSim - Westside Simulation Model using IWFM platform
WetManSim - Wetland Management Simulation Model

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Data Management

Data management services will be provided for data that derive from a single data source, and have been reviewed for quality control. All time series data will be uploaded into a DSS database file in both daily (when available) and monthly formats. The DSS database platform is selected because of its extensive use in CalSim and WestSim. Other file formats that can be exported from DSS include delimited text and Microsoft Excel files. The naming convention for each data set will follow rules of nomenclature that are based on CalSim 3.0 for consistency throughout the study area. Nomenclature includes, but is not limited to, the list of prefixes shown in Table 6-4.

Table 6-4. Data Management Prefix Nomenclature

Data Prefix	Data Type
C_	Channel
D_	Diversion
R_	Return-flow
S_	Storage
SG_	Channel-seepage
SP_	River-spills
C	Flow-channel
D	Flow-delivery
S	Storage
R	Flow-return
L	Flow-delivery
G	Flow-channel
DN_	SW_delivery-net
DG_	SW_delivery-gross
GP_	GW-pumping
RP_	Riparian deliveries
RU_	Reuse
DL_	Delivery-loss
SR_	Surface-runoff
CT_	Closure-term
I_	Inflow
DEMAND_	Demand
I	Flow-inflow
R_	Demand unit-return flow
AW_	Applied-water
UD_	Urban-demand

Notes:
Nomenclature prefixes based on CalSim 3.0

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Chapter 7
References

Chapter 7
References

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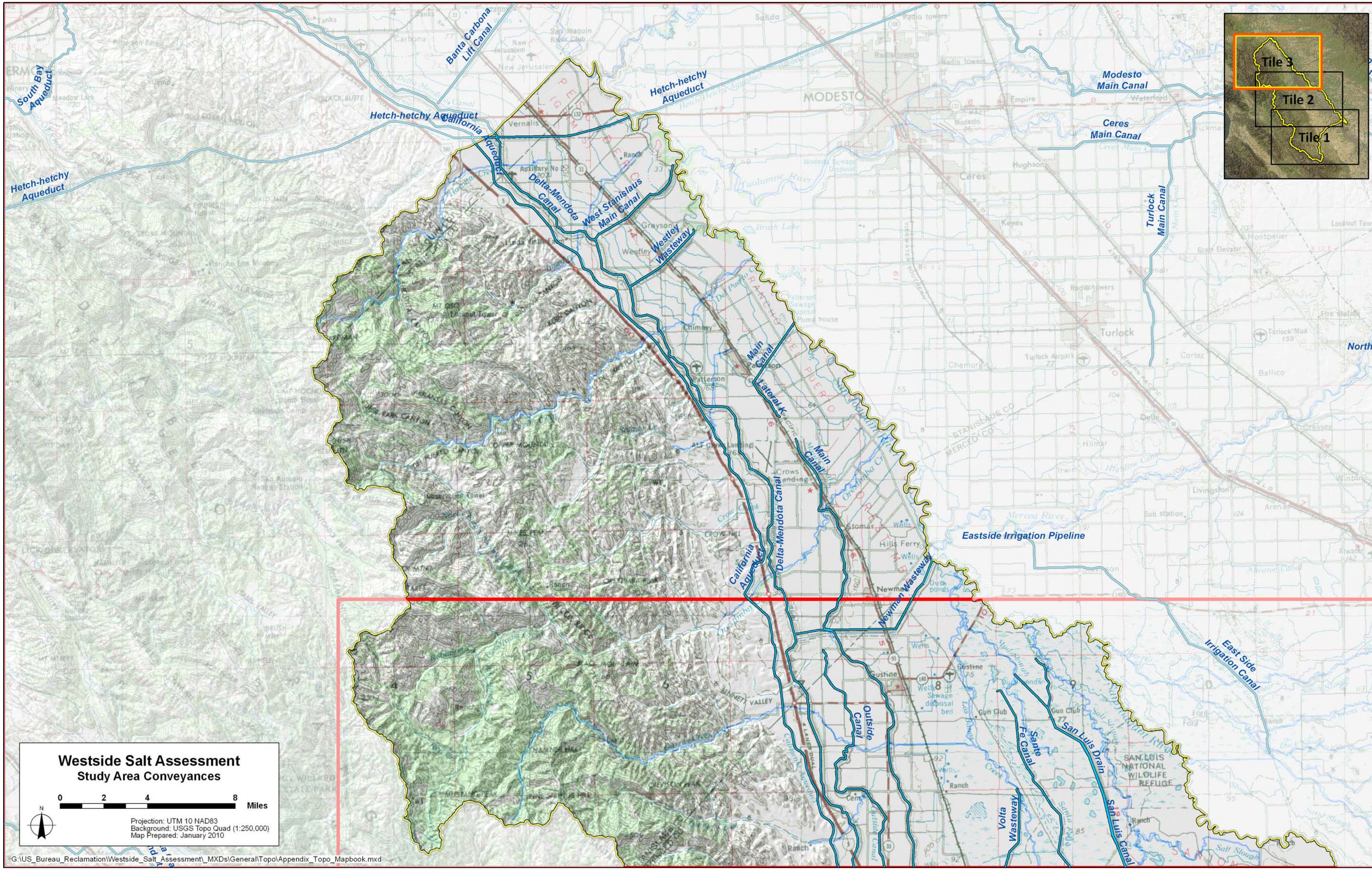

Plate 1. Canal and Drainage System, Sheet 1 of 3

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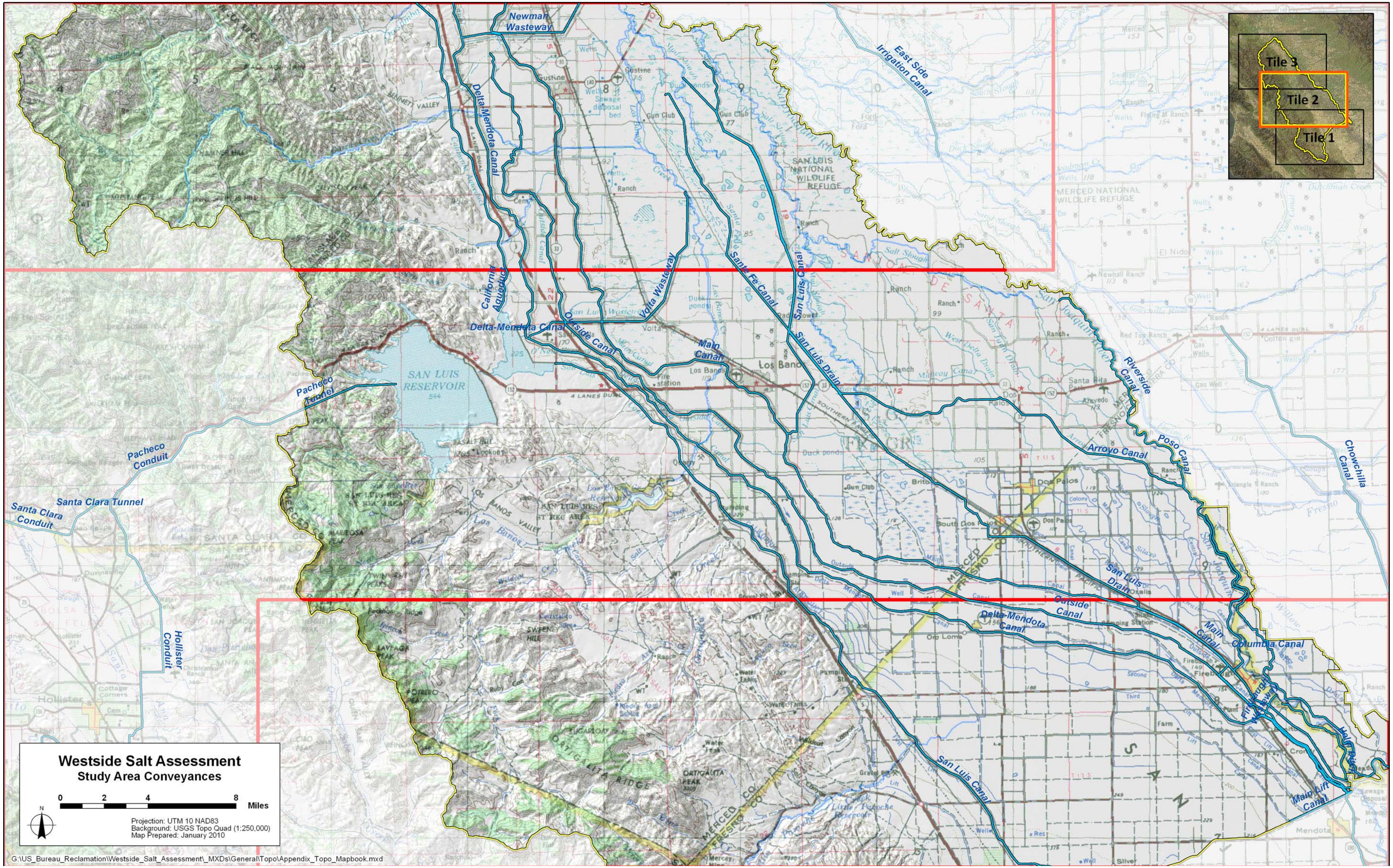

Plate 2. Canal and Drainage System, Sheet 2 of 3

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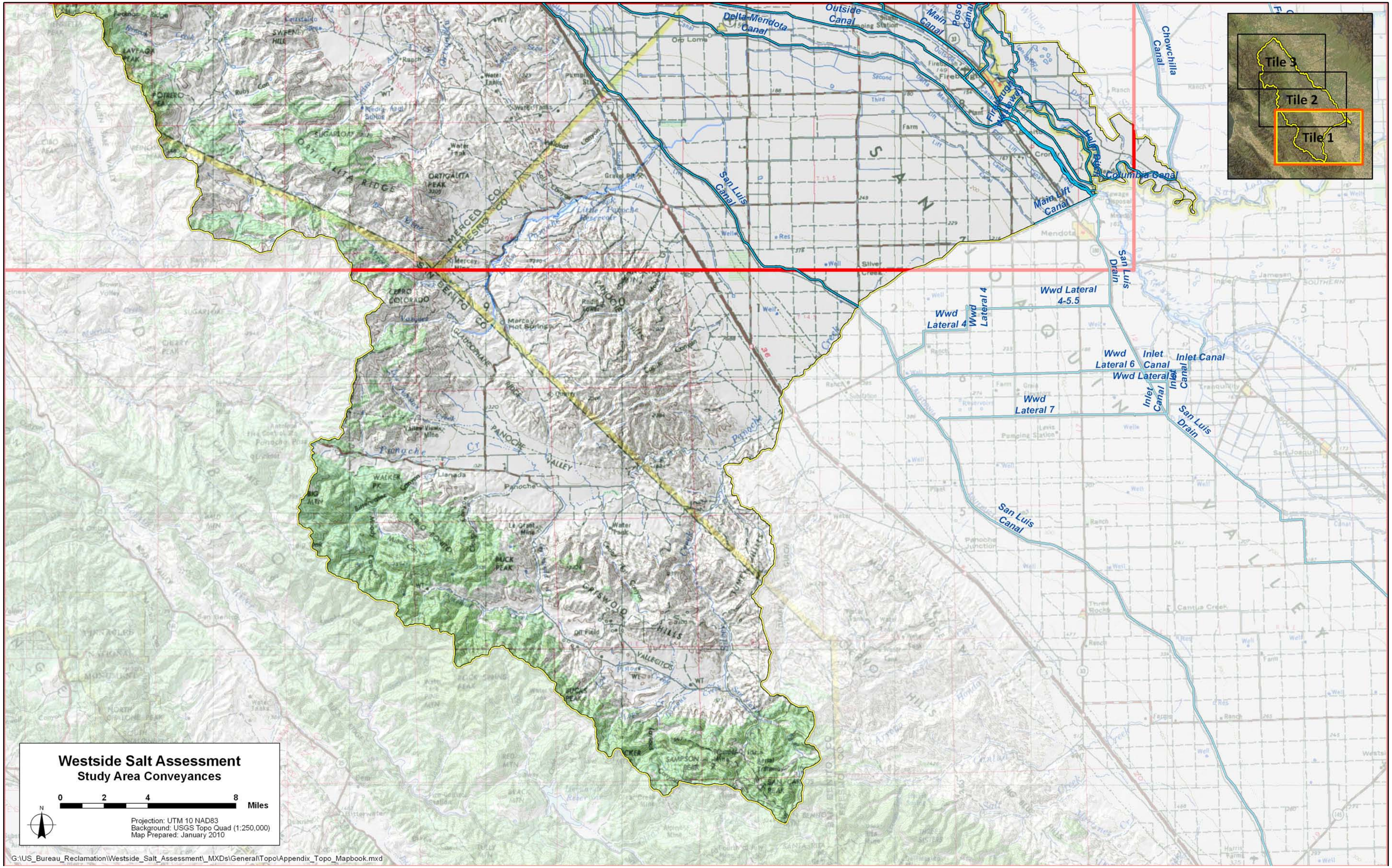

Plate 3. Canal and Drainage System, Sheet 3 of 3

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